MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

EDUCATION FOR LEADERSHIP

Engineering education, reflecting closely the attitude of engineers heretofore, has confined its work almost exclusively to scientific and technical training, giving little if any attention to the social and human aspects of engineering enterprises. The American Engineering Council, therefore, speaking for the engineering profession, urges upon engineering colleges an increased attention to the social aspects of engineering activities and a broadening of their technical training, in every way possible, to develop in engineering students the spirit of and a capacity for active leadership, not only in industry but in public affairs.

Resolution of American Engineering Council

MARCH 1923

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Contributors and Contributions

The Machine-Tool Industry

E. F. DuBrul

Speakers at a recent joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, approached the subject of the machine-tool industry from three different angles. Ernest F. DuBrul, Cincinnati, Ohio, discussed some of its economic features, Benjamin P. Graves and James A. Hall, Providence, R. I., the effect of variations in design of milling cutters on power requirements and capacity, and Dexter S. Kimball, Ithaca, N. Y., the development of machine tools.

Mr. DuBrul, who is general manager of the National Machine Tool Builders' Association and president of the Pyro Clay Products Company, was graduated from Notre Dame University and did graduate work at Johns Hopkins University. From 1897 to 1911 he was director and superintendent of the Miller, DuBrul & Peters Mfg. Co., and its president from 1915 to 1919. Mr. DuBrul analyzes costs and compares productivity of large and small shops.

The paper by Messrs. Graves and Hall, setting forth the results of investigations to determine the effect of changes in the design of milling cutters, will be found of great practical value. Mr. Graves is a graduate of the Rhode Island School of Design, class of 1904, where for six years he instructed evening classes in machine-tool design. Since 1915 he has been milling-machine engineer for the Brown & Sharpe Manufacturing Co., in charge of all milling-machine designs and problems, both for shop use and outside sources.

The co-author of the paper, Professor Hall, was graduated from Brown University in 1908 and has been giving instruction and conducting research there since that time. He is now associate professor of mechanical engineering. He is also president of the Providence Engineering Society.

Dean Kimball's address pays tribute to all those who have contributed to the development of machine tools from their crude beginnings to the modern standards of accuracy and output.

Progress in Steam Research

The first record of progress in the research of the properties of steam for the formulation of new steam tables appears in this issue. Dr. R. V. Kleinschmidt gives the results obtained in experiments at Harvard on the Joule-Thomson effect and Dr. Keyes of M.I.T. and Mr. Osborne of the Bureau of Standards tell of the progress made in designing apparatus for the parts of the work they are to carry on. These reports were originally presented at the A.S.M.E. Annual Meeting in December, 1922.

Elasticity of Pipe Bends

Sabin Crocker and Sterling S. Sanford, both of whom are associated with the Detroit Edison Company, have contributed to this issue an article on the elasticity of pipe bends. Both Mr. Crocker and Mr. Sanford were born in Mt. Clemens, Mich., and were graduated from the University of Michigan. Except for their war service they have since been connected with the Detroit Edison Company, where Mr. Crocker is now piping engineer and Mr. Sanford research engineer.

Vocational Training for the Industries

This issue contains a review of the present status of the many types of industrial education which proves that such education has already advanced in a truly remarkable way and promises much for the future. Members of the A.S.M.E. Committee on Education and Training for the Industries who prepared this report are James A. Moyer, Robert L. Sackett, and Charles R. Richards. Professor Moyer was graduated from Harvard University in 1899, and taught engineering, mathematics, and experimental engineering there until 1904. After two years in engineering work for the General Electric Company and one for Westinghouse, Church, Kerr & Co., he reëntered the teaching profession as professor of mechanical engineering at the University of Michigan. In 1912 he transferred to Pennsylvania State College, and since 1915 he has been director of the university extension work of the Massachusetts Department of Education.

Dean Sackett is a University of Michigan graduate, class of 1891. Previous to 1915 he was professor of sanitary and hydraulic engineering at Purdue University, and since that time he has been dean of the school of engineering at Pennsylvania State College and director of its engineering-experiment station and engineering extension.

Professor Richards received the degree of M.E. from Massachusetts Institute of Technology in 1885. He has served successively as director of the Department of Science and Technology, Pratt Institute, director of the Department of Manual Training, Teachers' College, Columbia University, and director of Cooper Union. He has also been special agent of the N. Y. Department of Labor, and was for two years secretary of the National Society for the Promotion of Industrial Education.

Design of Woodworking Machinery

Woodworking machinery of the future will be greatly influenced by such factors as the adoption of high-speed steel, demands of greater economy, power and speed, the use of ball bearings, and the direct application of the electric drive. Sern Madsen discusses these factors in the present issue. He was graduated from the State College at Ames, Iowa, in 1911, receiving his M.E. from that institution in 1916. He was for a time superintendent of maintenance and power for Curtis Brothers & Co., Clinton, Ia., and since 1918 has been superintendent of plant equipment for the Curtis Companies, Inc., of Clinton.

A.S.M.E. Pacific Coast Regional Meeting

Los Angeles, April 16-18, 1923

For Details of Program and Interesting Excursions, See Current Numbers of A.S.M.E. NEWS

A.S.M.E. Spring Meeting, Montreal, May 28-31, 1923

MECHANICAL ENGINEERING

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Economic Features of the Machine-Tool Industry

Some of the Features Brought Out as a Result of Analyzing the Statistics of the 1919 Census of Manufacturers—Problems of Management—Trade Evils and Their Remedies

By ERNEST F. DUBRUL,[1] CINCINNATI, OHIO

VERY few people give thought to the vital economic fact that without the organizing, imaginative minds of business leaders there would have been little material progress in the world. Those who propose untried industrial systems for dreamlands never think of it at all. Without free play for the adventurous, creative, pioneering spirit of those who can organize and direct industry, the world would soon slip back in its achievements of the comforts and luxuries that it enjoys. Only the joint effort of business brains and mechanical brains keeps us as we are, and pushes us on.

We hear much loose talk about the rich getting richer and the poor getting poorer in these days when the streets are full of poor men's automobiles. By the use of machinery, directed by the organizing minds of business leaders, the productivity of the nation has increased in the last century about twenty times as fast as the population, and cold statistics prove the truth to be that the poor are getting richer with the rich. Progress will continue at an increasing rate, unless stopped by attempts to put in practice such suicidal dreams as have been tried in Russia.

Consider how little of man's work continues in existence for 100 years. Most of it is replaced before worn out by better and more adaptable plant. Even if we made no advances in methods we would have to keep on replacing the old, as the forces of nature soon destroy the handiwork of man. All this requires that some men must look forward many years to a demand from unborn generations.

Only because some men looked far ahead to such demands of our present generation have we the comforts we enjoy. Only because some men could save capital, and do so in reasonable security, are present productive processes giving us these comforts. Only as this generation saves something out of consumption and puts it to work, can future generations have greater comfort.

An impression of the rapid growth in productivity is obtained from comparison of the estimated value of manufactures which in 1812 was $170,000,000 for the United States, whereas in 1919 it was over $62,000,000,000. Of this total, 1$^1/_2$ per cent, or nearly one billion, was industrial machinery alone, to say nothing of of electrical equipment, automotive or other vehicles, tractors, agricultural machinery, railway cars, and locomotives. Of the industrial machinery, machine tools form the largest single class and in value it is about twice as large as the next largest class, textile machinery.

Because the blacksmith made the tools for all the other workers who built the temple of Solomon, the legend is that King Solomon honored the blacksmith above all the other workers. The modern machine-tool builder now stands in that blacksmith's place, producing the master tools for all other crafts.

TABLE 1 DATA FROM U. S. CENSUS OF MANUFACTURES, 1919

Reduced to "Per Shop" and "Per Wage-Earner" Basis

	All Industries			Machine Tools		
	Totals	Per Shop	Per Wage Earner	Totals	Per Shop	Per Wage Earner
Number of establishments	290,105	....	......	403	....	......
Average number of wage earners	9,096,372	31	......	53,111	132	......
Nunber of salesmen, clerks, etc	1,033,507	5	......	6,186	15	......
Number of superintendents and managers	281,253 }		......	1,696 }		......
Number of corporation officers	132,467 }	2	......	637 }	5	......
Number of proprietors	269,137 }		......	132 }		......
Total number of persons engaged	10,812,736	38	......	61,762	152	......
Capital employed	$44,558,593,771	$153,594	$4,898	$231,039,843	$573,298	$4,350
Turnover	140	......	....	92	......	....
Value of product	$62,418,078,773	215,156	6,862	212,400,158	527,047	3,999
Material used	35,730,393,727	123,163	3,927	56,048,334	139,077	1,055
Fuel and power rented	1,645,986,556	5,674	180	2,985,974	7,409	56
Value added by manufacturer	25,041,698,490	86,319	2,753	153,365,850	38,056	2,887
Wages paid	10,533,400,340	36,308	1,157	66,178,969	164,215	1,246
Salaries paid	2,892,371,494	9,971	318	18,037,856	44,759	340
Contract work	464,403,700	1,601	51	1,469,844	3,648	28
Rents	212,043,089	731	23	476,353	1,182	9
Taxes—federal	1,790,197,060	6,170	197	15,755,796	39,096	296
Taxes—state	289,172,297	997	32	2,083,106	5,169	39
Tot. (Deductions from Av.)	$16,181,587,980	$ 55,578	$1,778	$104,001,924	$258,069	$1,958
Residue	8,860,110,510	30,541	974	49,363,926	122,491	929
Interest on capital at 7 per cent	3,119,101,563	10,752	343	16,172,789	40,130	304
Net residue	$ 5,741,008,947	$ 19,789	$ 631	$ 33,191,137	$ 82,361	$ 625

I shall give you an outline picture of the machine-tool industry through some analysis of the statistics of the Census of Manufactures of 1919. This census gives the number of establishments, capital employed, value of product, costs of material, fuel, power, wages, salaries, contract work, rents, taxes, number of wage earners and salaried employees. To get our first comparison we reduce this data to a "per shop" basis, and also to a "per wage earner" basis as set forth in Table 1.

From the "per shop" figures we see that the average machine-tool shop is about four times as large as the average of all industries, as shown by the items of capital, number of wage earners, added value, wages, salaries, etc.

The size of his shop shows the machine-tool man to be a good manager, and some other things confirm this. He paid his men better than the average employee got elsewhere, but his salary roll was less in proportion and the number of supervising personnel also smaller in proportion. While salaries formed 27.3 per cent of the payroll of the average shop, they show as only 21 per cent of the payroll of the machine-tool shop.

[1] General Manager, National Machine Tool Builders' Association. Mem. Am.Soc.M E.

Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923. Slightly abridged.

TABLE 2 DISTRIBUTION BASED ON VALUE ADDED BY MANUFACTURE AS 100 PER CENT

	All Industries	Per cent	Machine Tools	Per cent
Value added by mfr.	$25,041,698,490	100	$153,365,850	100
Capital employed	44,558,593,771	177	231,039,843	150
Value of product	62,418,078,773	249	212,400,158	138
Material used	35,730,393,727	142.5	56,048,334	36.5
Fuel and power rented	1,645,986,556	6.5	2,985,974	1.5
Wages paid	10,533,400,340	42.1	66,178,969	43.2
Salaries paid	2,892,371,494	11.6	18,037,856	11.8
Contract work	464,403,700	1.9	1,469,844	1.0
Rents	212,043,089	0.8	476,353	0.2
Taxes—federal	1,790,197,060	7.1	15,755,796	10.3
Taxes—state	289,172,297	1.2	2,083,106	1.4
Residue	8,860,110,510	35.3	49,363,926	32.1
Interest on cap. @ 7%	3,119,101,563	12.4	16,172,789	10.5
Net Residue	$ 5,741,008,947	22.9	$ 33,191,137	21.6

TABLE 3 DISTRIBUTION BASED ON VALUE OF PRODUCT AS 100 PER CENT

	All Industries	Per cent	Machine Tools	Per cent
Value of product	$62,418,078,773	100	$212,400,158	100
Capital employed	44,558,593,771	71.4	231,039,843	108.7
Material used	35,730,393,727	57.3	56,048,334	26.3
Fuel and power rented	1,645,986,556	2.6	2,985,974	1.4
Value added by mfr.	25,041,698,490	40.1	153,365,850	72.3
Wages paid	10,533,400,340	16.9	66,178,969	31.2
Salaries paid	2,892,371,494	4.6	18,037,856	8.5
Contract work	464,403,700	0.7	1,469,844	0.7
Rents	212,043,089	0.3	476,353	0.3
Taxes—federal	1,790,197,060	2.9	15,755,796	7.4
Taxes—state	289,172,297	0.5	2,083,106	1.0
Residue	8,860,110,510	14.2	49,363,926	23.2
Interest on cap. @ 7%	3,119,101,563	5.0	16,172,789	7.6
Net Residue	$ 5,741,008,947	9.2	$ 33,191,137	15.6

TABLE 4 FIGURES CLASSIFIED ACCORDING TO SIZE OF SHOPS

	Machine Tools					
	All Shops	$20,000 & Under	$20,00 to $100,000	$100,000 to $500,000	$500,000 to $1,000,000	Over $1,000,000
No. of establishments	403	66	110	134	41	52
Per cent	100	16.4	27.3	33.2	10.2	12.9
No. of wage earners	53,111	245	1,941	8,162	7,235	35,528
Per cent	100	5/10	3.7	15.3	13.6	66.9
Per shop	132	4	18	61	176	683
Capital { Distributed by % Val. of Product	$231,039,843	$693,120	$6,469,116	$34,655,976	$30,266,219	$158,955,412
Per cent	100	3/10	2.8	15	13.1	68.8
Per shop	573,298	10,500	58,810	258,634	738,200	3,056,834
Per wage earner	4,350	2,829	3,332	4,246	4,183	4,474
Value of product	212,400,158	615,394	6,026,556	31,759,941	27,856,054	146,142,213
Per cent	100	3/10	2.8	15	13.1	68.8
Per shop	527,047	9,324	54,786	237,015	679,415	2,810,427
Per wage earner	3,999	2,511	3,105	3,891	3,850	4,113
Materials & power	59,034,308	230,752	2,049,589	10,271,346	7,846,590	38,636,031
Per cent	100	0.4	3.5	17.3	13.2	65.6
Per shop	146,486	3,497	18,632	76,651	191,380	743,000
Per wage earner	1,111	942	1,055	1,258	1,085	1,087
Value added by mfr.	153,365,850	384,642	3,976,967	21,488,595	20,009,464	107,506,182
Per cent	100	0.3	02.6	14	13	70.1
Per shop	380,561	5,858	36,154	160,385	488,035	2,067,426
Per wage earner	2,887	1,570	2,048	2,632	2,765	3,025
Wages { Distributed by % No. of W. E.	66,178,969	304,423	2,415,532	10,165,090	9,020,194	44,273,730
Per shop	164,215	4,613	21,960	75,858	220,000	851,418
Per wage earner	1,246	1,246	1,246	1,246	1,246	1,246
Remainder { For Expense and Profit	87,186,881	80,219	1,561,435	11,323,505	10,989,270	63,232,452
Per cent	100	1/10	1.8	12.7	12.8	72.6
Salaries } Distributed by % of Remainder for Expense and Profit	18,037,856	18,038	324,861	2 290,808	2,308,845	13,095,484
Contract W. H.	1,469,844	1,470	26,457	186,670	188,140	1,067,107
Rents	476,353	476	8,574	60,496	60,974	345,833
Taxes—federal	15,755,796	15,755	283,605	2,000,986	2,016,742	11,438,708
Taxes—state	2,083,106	2,083	37,496	264,554	266,638	1,512,335
Total	$ 37,822,955	$ 37,822	$ 680,813	$ 4,803,514	$ 4,841,339	$ 27,459,467
Per shop	93,853	573	6,189	35,847	118,081	528,067
Per Wage earner	712	154	350	588	669	772
Residue	49,363,926	42,397	880,622	6,519,991	6,147,931	35,772,985
Int. on capital @ 7%	16,172,789	48,518	452,838	2,425,919	2,118,635	11,126,879
Net Residue	$ 33,191,137	—6,121	$ 427,784	$ 4,094,072	$ 4,029,296	$ 24,646,106
Per cent	100	0	1.3	12.4	12.1	74.2
Per shop	82,360	—92	3,889	30,552	98,275	473,963
Per wage earner	624	—24	220	501	556	693

TABLE 5 RATIO OF ALL ITEMS TO TOTALS, PER CENT

	All Industries						Machine Tools					
	Totals	20M & Under	20M to 100M	100M to 500M	500M to 1000M	Over 1000M	Totals	20M & Under	20M to 100M	100M to 500M	500M to 1000M	Over 1000M
No. of establishments	100	52.7	26.8	13.7	3.2	3.6	100	16.4	27.3	33.2	10.2	12.9
No. of wage earners	100	3.2	8.7	18.9	12.3	56.9	100	0.5	3.7	15.3	13.6	66.9
Capital employed	100	1.8	5.7	14.4	10.4	67.7	100	0.3	2.8	15.0	13.1	68.8
Value of product	100	1.8	5.7	14.4	10.4	67.7	100	0.3	2.8	15.0	13.1	68.8
Material & power	100	1.2	4.9	13.0	9.6	71.3	100	0.4	3.5	17.3	13.2	65.6
Value added by mfr.	100	2.6	7.0	16.6	11.5	62.3	100	0.3	2.6	14.0	13.0	70.1
Wages paid	100	3.2	8.7	18.9	12.3	56.9	100	0.5	3.7	15.3	13.6	66.9
Salaries, rents, Contract wk. Taxes—federal & state	100	0.1	1.8	12.7	12.8	72.6	100	2.1	5.7	14.9	11.0	66.3
Residue (net)	100	2.3	5.8	15.2	11.2	65.5	100	0.	1.3	12.4	12.1	74.2

The item of added value is the index of manufacturing activity. This item excludes material from the total value. The manufacturer's function is to convert material into finished product. Of this added value the machine-tool salary roll was only 11 per cent while the average was 16 per cent, so evidently he was not extravagant in that particular.

After taking out of the total value all the amounts specified, there still remains a balance, designated as "residue" for want of a better term. As the census figures do not go into further detail, we can only say that this residue still includes costs like depreciation, obsolescence, insurance, advertising repairs, interest, legal, patent, auditing, traveling, and all other expenses not covered by the specific expenses mentioned. It would be proper to deduct from this an allowance for interest on capital which in 1919 at the going rate was easily 7 per cent. This would allow the average shop $19,720 and the machine-tool shop $82,361. From the "per wage earner" figures we note that the machine-tool builder used $600 less capital than the average.

The average manufacturer took $4100 worth of material and fuel per wage earner in 1919, and by processing added to it $2752 worth of utility, or 66 per cent. But the creative machine-tool builder took $1100 of material per wage earner and added $2887 or 262 per cent of utility to it. As the real function of all manufacturers is to add utility, it would seem fair to compare them by using, as a base, the value added. Table 2 reduces the various factors to a percentage of this base. From this we deduce that to produce $100 of added value at the market price of his goods, the average manufacturer employed $177 of capital against the machine-tool builder's $150. The average used $149 of material against the machine-tool builder's $38. It cost them both about the same in expenses specified, except that Federal taxes took $3 more out of the machine-tool builder. If now we allot 7 per cent interest on the capital invested in each case, the average manufacturer got a net residue somewhat greater than the machine-tool builder.

Table 3 gives the various components of total value, and shows the machine-tool builder as having a larger percentage of residue.

Table 4 is an attempt to get the residue down to a "per wage earner" basis, by classes according to the size of the establishment. Deducting wages from added value shows a still greater concentration of the remainder in the large shops. We next distribute the salaries, taxes, etc., in proportion to this last balance. This is overloading the small shop with Federal taxes that it may not have paid, as its earnings were smaller per man and it had an exemption of $2000. On the other hand, there is some counterbalance to this overload, because the overhead per wage earner is larger in the small shops than in the large ones. This is true in spite of the notions of many proprietors of small shops and officers of small corporations who do not pay themselves the salaries they could earn elsewhere, and thereby deceive themselves into thinking their overhead is low. On the whole, the method here used probably gives them a better showing in wages, in expense items, and in residue per wage earner than the facts warrant.

From these figures some interesting suggestions arise as to machine-tool builders. Note the small residue per wage earner left in

shops below the $100,000 line, which is not enough to pay interest, to say nothing of allowing for other expenses and profit. The men who have these small shops seem to be taking a very long chance that they can ill afford to take. Yet 44 per cent of the machine-tool builders were doing that very thing

It is worth noting that although machine-tool shops must employ a highly skilled force of wage earners, and their force is larger in each class than the average, still in each class the residue per wage earner was less than the average, though this residue increases with the size of the shop, as we would expect.

Table 5 throws some interesting light on the concentration of industry in large establishments. The net residue percentage for each class compared to the percentage of number of establishments would indicate that while a larger proportion of machine-tool shops are in the million-dollar class, and while the proportion of net residue is also higher in this class of machine-tool shops than for all industries, the relative concentration is over three times greater in all industries than in the machine-tool industry.

Table 5 shows that while small shops are numerous, the greatest bulk of production is effected in shops turning out $1,000,000 worth of product or more. While the shops turning out less than $100,000 per year are nearly 80 per cent of the general total, they employ only 12 per cent of the wage earners, to say nothing of the mass of proprietors, etc., not listed as wage earners. Then they succeed in producing less than 10 per cent of the added value. The small machine-tool shops, almost 44 per cent of the number, produce only 3 per cent of the added value with their proprietors and 4 per cent of the wage earners.

Note the concentration of 70 per cent of the added value in about 13 per cent of the machine-tool shops that averaged $2,000,000 of added value and $3,000,000 of capital. Nobody ordered this concentration, it developed very naturally. Consolidations have been very few in the industry; it got its million-dollar shops, its half-million dollar shops and its hundred-thousand dollar shops by grinding thrift and hard work.

The high level of management in the machine-tool business is indicated by the fact that 13 per cent of the machine-tool builders are in the $2,000,000 group of value adders, whereas only $3^1/_2$ per cent of the average manufacturers are in the $500,000 class. Moreover 10 per cent of the machine-tool men are in the $500,000 class compared to 3 per cent of average manufacturers in the $300,000 class. Again, 33 per cent of machine-tool men are in the $250,000 class, while only 13 per cent of average manufacturers are in the $100,000 class. And only 44 per cent of adventurous machine-tool builders are in the two lower classes compared with 79 per cent of all manufacturers in those classes, and the figures seem to indicate that such small shops must have very hard sledding in the machine-tool business.

Problems of Management of Machine-Tool Shops

The fluctuating nature of the demand for machine tools creates serious problems in different stages of the business cycle. It is evident that the more regular an industry's demand, the lower can be its costs and the easier its managerial problems. The peculiarities of human nature as manifested in business cycles compel the builder of machine tools to face relatively short and sharp peaks of activity, followed by relatively long and deep depressions. The industry has a naturally bad load factor for some very human reasons. The first is that most people do not look very far ahead, and most machine-tool users are no different in that particular. Therefore, comparatively few users forecast their machine-tool requirements to any great extent. In a period of depression the user's shop is more or less idle, and he has more than enough machinery to supply the restricted demand for his own goods. He is mentally so depressed by dull business that he cannot bring himself to even think of a time just a few months ahead when his business will be more active, when the natural growth of population and wants will demand more of his goods than he was able to make in his last boom. Not forecasting what the future has in store, and how long the depression in his own business will last, he simply will not spend money on plant improvements when he could be making them to the best advantage.

Consider now the difficulties of the machine-tool builder in trying to regulate his operations. At the height of his own previous boom he had as full a force of men as he could get, working night and day. He had also a lot of contracts out for castings and other material, placed far in advance, in large quantity, at high prices, to be able to supply his customers' wants without delay. Even though he had been quoting six to eighteen months' delivery, his orders had been piling in on him with increasing speed. When his orders began to fall off he had this large impending inventory thrown on his shoulders. Then he got many cancellations, from those who should have been compelled to live up to their contracts. If he was unwise enough to accept them he was stuck with large inventories in all stages of completion, but without sale.

Being of the adventurous rather than of the prudent type, and of the inventive rather than of the commercial turn of mind, he had not given much consideration to the progress of the business cycle. As the economics of the cycle had not been pointed out to him, he did not realize that his industry is among the first to slump in a cycle, and that the slump in machine-tool orders is merely one of the signs of coming trouble elsewhere. He took counsel of hope rather than of prudence. It had cost him so much in money and effort to get his working force together that he hated to break it up. If his product was not of a type built only to order, he kept on working and built stock instead of shutting down his plant. Then, too, he had a goodly share of that human sympathy that leads any decent employer to keep his men employed as long as possible rather than to throw them out of work. Looking back now he realizes that it would have been better both for his men and for himself to have shut down as his orders were filled, and to have waited to build his stock at the bottom of the depression rather than at the crest of a boom.

When his own financial strength was threatened, even the most adventurous and sympathetic could no longer keep on producing, at high costs, machines for which there was no sale at any price. So the industry finally had to do late what it should have done early in the slump, that is, shut down and wait for improvement in conditions in other lines to revive demand for machine tools.

Not only is the period of carry over likely to be long, but another danger of carrying large stocks must be reckoned with. That danger lies in obsolescence of designs. Necessity is the mother of invention, and the necessity of getting work for idle shops always produces a good-sized family of new and improved designs after a depression has been on for some time. When these are brought forth, their greater utility to the user kills the demand for the older types. In a depression, machines of new design can generally be made for less than the old types had cost in the boom. Even if not obsolescent the replacement cost of the older type is less in a depression that it was in the boom. Some competitor who has no knowledge of unchangeable economic facts is almost certain to hatch the bright idea that by making very low prices while his competitors are asleep, he can get a much larger participation out of a dull market than his natural participation had been in a more active market. He thinks he can thereby carry some of his overhead at their expense. But as the competitors are not asleep, this bright idea fails to get the anticipated results. All have a natural desire to keep their own places in the sun and they meet his low prices and all get that much less to carry overhead with. While all these factors lead to great losses in a depression, the low prices do not lead to much, if any, stimulation of sales.

For 15 months in the last two years machine-tool-sales volume was down to less than 15 per cent of what it had been in the first quarter of 1920. For 32 months past the demand has averaged about 23 per cent of that figure. In some cases prices were made that would just about cover material and labor, in attempting to coax out orders enough to hold a force of good men together. Some people think that because demand for cheap automobiles can be stimulated by slight reductions in price, the demand for machine tools acts in the same way. The cheaper the automobile, however, the wider is the stratum of demand it can tap, until a saturation point is reached.

Because of these long periods of depression through which the machine-tool builder must carry his plant and organization, he must put a heavy stand-by charge on his goods. He must cover this cost of necessary idleness—over which he has no control—by accumulating a reserve in good times out of which to draw in bad

(Continued on page 200)

The Development of Machine Tools

By DEXTER S. KIMBALL,[1] ITHACA, N. Y.

IN THESE days of many books and much learning we are prone to overlook or forget the fact that man's upward progress in all times has been dependent primarily upon the tools and mechanical appliances at his command. Originally little better than the beasts of the field, man lifted himself from their company by discovering the use and control of fire, and with the invention of the bow and arrow he began to assume his lordship over all created living things. The ability to make pottery advanced him from savagery to barbarism, and the domestication of animals gave him a supply of physical strength far greater than his own to assist him in conquering an unfriendly environment.

The ability to smelt copper and tin into bronze gave him tools and weapons of greatly increased efficiency and enabled him to establish himself securely in permanent habitations where he could till the soil, tend his herds, and have some leisure for thought. From this opportunity to think came the alphabet and written language, and with this ability to record and transmit his thoughts came civilization. Finally the discovery of iron and steel and of almost unlimited power from coal and water power have enabled this master animal to push his ideas of civilization to a height undreamed of by his ancestors, and it has not been possible to predict what the end may be.

Man is distinguished, therefore, from other inhabitants of the animal world principally by his power to make and use tools and with their aid to subdue his physical surroundings to satisfy his needs. These tools are of two distinct kinds. First come those that he has developed to supplement his own puny strength and to increase his effectiveness. The story of the development of power-supplying devices from the first crude hatchet to the monster power stations of today is in itself an epic unequaled by anything else except, perhaps, the parallel development of the art of transmitting intelligence. The story of man's progress from signaling with fire or smoke to modern radiotelephony is without doubt man's most spectacular achievement as it is also one of his most useful accomplishments.

But a supply of power of itself alone would not have been sufficient for man's needs. Methods of utilizing and guiding this power so that it would perform useful work were essential requirements for progress. Of a necessity machines were needed that would perform the operations of industry as well or better than they could be performed by the human hand. The second great division of this field, therefore, comprises the tools that involve "transfer of skill." Practically all tools that are actually used in productive processes involve this principle. The stone ax, the bow and arrow, and all handicraft tools have come into being in answer to a desire on the part of some one to improve his product in quality or quantity by the aid of some one of these implements.

Until the middle of the eighteenth century the use of tools as then developed still required a considerable degree of skill on the part of those operating them. The tool was still only an adjunct to the skill of the worker. About that time, however, a series of interesting inventions demonstrated the possibility of making machines involving such a large transfer of skill as to make the worker an adjunct to the machine in many industrial processes. This is the essence of the Industrial Revolution, so called, and today automatic machines that perform the necessary operations with little or no human aid are in common use.

Back of the amazing array of productive tools and processes that now fill the land, stand a group of tools that are in a class by themselves. These may be called the "Master Tools of Industry" since the production of all other tools and processes, in the construction of which metal working is a necessity, depends upon the possession of some or all of these tools. This group consists of the lathe, the planer, the drilling machine, the boring mill, the milling machine, and the grinding machine, with their several modifications and derivatives. They constitute the group commonly known as "machine tools" and are familiar to all who are acquainted with machine production. This group of tools are worthy of special notice for they are basic implements and, as formerly remarked, accurate machine construction of all kinds depends absolutely upon them.

The primitiveness and inaccuracy of the machine tools in use when Watt began to build his steam engines are almost unbelievable. We find him complaining of one of his steam cylinders that "at the worst place the long diameter exceeds the short by three-eighths of an inch" and there is much other evidence that indicates similar crudity in all machine processes. The development from these crude beginnings to the modern standards of accuracy and output is something of which every engineer may well feel proud. It is difficult always to give due credit for great improvements in any line to all who have contributed to the accomplished result. Great inventions, so called, are usually the result of a long train of thought and experiment on the part of many men. But it is customary to give the greatest credit to the man who first makes a great idea a real working possibility. For this reason there are a few outstanding men among those who brought this great change about, though undoubtedly the ideas they put into practical working machines had occupied the minds of many of their predecessors. Wilkinson's boring machine solved Watt's difficulties so that Boulton writes of a fifty-inch cylinder that "does not err the thickness of an old shilling in any part." And there are many other names among these old pioneer English mechanics that should be held in everlasting remembrance when the names of all great warriors have been forgotten.

Outstanding Names in Machine-Tool History

There are, in the history of machine-tool development, three names that stand out in bold relief. The first of these is Henry Maudslay, who was born in 1771. Of the many inventions and improvements in machinery that came from this master mind the most important is the slide rest and its combination with the lead screw and change gears whereby threads could be machined. Until Maudslay's time the turning of metal had been accomplished by hand tools. In fact, this method persisted for many years after his day and there is now preserved in the rooms of The American Society of Mechanical Engineers a turning tool that was used by the late John Fritz not so many years ago. Maudslay finished the sides of his lathe bed and mounted upon it a saddle exactly as used on modern lathes, this saddle carrying a cross-slide in which the tool was rigidly held. The saddle was actuated by a lead screw and change gears as in all modern lathes. As Professor Roe truly says, "Too much value cannot be placed upon the slide rest and its combination with a lead screw operated by change gears. It is used in some form in almost every machine tool and is one of the great inventions of history." Maudslay's improvements constituted a transfer of skill that did much to start the modern industrial era.

The second great improvement in machine tools was the application of the turret to the slide rest so that a series of operations can be performed repeatedly without resetting the cutting tools. Here again we have an idea that was undoubtedly an old one; but it remained for an American, Henry David Stone, to make it a working possibility in the turret lathe built by him in 1858. Stone's first semi-automatic turret lathe carried four cutting tools on the cross-slide and six in the turret. His improvements rank in importance with those of Maudslay and they made possible most of the modern semi-automatic machine tools. Lastly came the invention of the universal cam or "brain wheel" by another American, Christopher Mines Spencer, which provided an automatic control for the combination of Maudslay's slide rest and Stone's

(Continued on page 168)

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Effect of Variations in Design of Milling Cutters On Power Requirements and Capacity

A Study of the Effect of Changes in the Number of Teeth, Spiral Angle, Rake Angle, and Cutting Speed of the Cutter on Power Consumption, Tendency to Chatter, and Stresses Set Up in the Machine

By BENJAMIN P. GRAVES[1] and JAMES A. HALL,[2] PROVIDENCE, R. I.

THE rapid development of the milling machine during the last two decades into a leading position in heavy machine work has brought about many improvements in the design of milling cutters. The old cutters with many teeth, no rake angle and a small spiral angle were very inefficient from a power standpoint, and it was only about twelve wears ago, following the delivery of a paper before the Society on Milling Cutters and Their Efficiency by A. L. DeLeeuw,[3] that "coarse-tooth" cutters having few teeth, a moderate rake angle, and a much larger spiral angle began to replace the earlier type.

While these cutters rapidly came into almost universal use for production work, little further was done to put the subject on a scientific basis until 1921 when the report of an elaborate piece of research work was presented before the annual meeting of the Society by Prof. John Airey and Carl J. Oxford.[4] Some of the conclusions which they presented differed so greatly from present practice that it seemed desirable to undertake a series of investigations at the plant of the Brown & Sharpe Mfg. Co. to determine the effect of changes in the design of milling cutters. The results obtained are presented in this paper, which comprises a study of the effect of changes in the number of teeth, spiral angle, rake angle, and cutting speed of the cutter on power consumption, tendency to chatter, and stresses set up in the machine.

Choice of Methods

The first consideration in the choice of methods to be followed was that all tests as far as possible should be made under actual shop conditions, using, however, sufficient refinement of measurement to give a high degree of accuracy in the results. On the other hand, as cutters and not machines were to be compared, any variables due to the machine alone must be eliminated. It therefore seemed best to make most of the tests with the work held rigidly on the milling-machine table and to determine the power used by the cutter from the figures of the input into the motors driving the machine.

An old-style Brown & Sharpe No. 3 heavy plain milling machine with a constant-speed drive shaft was available for the tests. Upon the table of this machine a fixture was placed into which dovetailed steel specimens 6 in. wide and 18 in. long could be fastened by mean of a gib. This made about as rigid a means of support as could be devised. The cutters were also rigidly held as they were keyed on to a $1^1/_2$-in. arbor, arbor supports were used on both sides of the cutter, and the outside braces were bolted during all of the tests. In this way errors due to distortion or vibration in the machine or arbor were eliminated as far as possible.

Measurement of Power Used by Cutter

The power figures desired in making comparisons between cutters are the amounts required by the cutters alone and should not include the friction losses in the machine unless the friction has some direct relation to the pressure exerted or power required by the cutter. The problem is complicated by the fact that the power delivered to the milling machine is divided between a slow-moving table and a cutter running at a relatively high speed. Furthermore, these two drives are of widely different efficiencies.

The first step toward getting definite information concerning power requirements was obviously to drive the spindle and table by separate motors. A prony brake was then placed on the arbor and a series of tests run to get the efficiency of the spindle drive at different capacities and speeds. The power input required to run the arbor at no load varied slightly with the speed and condition of lubrication. The brake-horsepower output, however, was always nearly the same for any added kilowatt input over the no-load reading. A horsepower-kilowatt curve was then drawn where the power delivered to the arbor was one coördinate, and the difference between the no-load kilowatt reading and the reading under load the other. One objection to the above method might be that the pressures between the arbor bushings and arbor supports are much greater under cut than on a prony-brake test and that the authors have charged this friction loss to the cutter. However, not only is this a very small amount but it is one that is properly charged to the cutter rather than to the machine.

The proper treatment of the power required by the table is a more difficult problem. Here the no-load kilowatt reading includes the motor losses and the friction losses in all of the bearings up to the table clutch, and these losses remain nearly constant for all loads. The additional power required when the table is operating under load is not only that needed to overcome the pressure of the cutter, but a much greater amount due to the friction loss in the lead screw and thrust bearing caused by that pressure. As this friction varies with the pressure, it seems obvious that it should be charged against the cutter if conditions calling for different pressures are to be compared. The authors therefore took as the net power required by the table the difference between the motor output under load and that when driving the feed mechanism alone.

Any milling-machine table drive is necessarily of low efficiency due to the fact that the table must not continue to move and drive the lead screw after the table clutch is thrown out. This limits the efficiency of the drive to a reasonable margin of safety below 50 per cent when operating on a high-speed return and of course gives a much lower figure at cutting speeds. This low efficiency makes little difference under ordinary conditions as a very small proportion of the total power of the machine is taken by the table. This would be changed if the practice of using low cutting speeds were carried to an extreme. Considerable attention was paid to this condition in the tests and it is further discussed later in the paper.

Cutters

High-speed-steel cutters $3^1/_2$ in. in diameter were used on practically all of the tests, the only exception being a few tests with two 6-in. side milling cutters. All of the $3^1/_2$-in. cutters used in the tests to determine the effect of the number of teeth had 30-deg. spiral angles and 10-deg. rake angles. As the formula derived by Professor Airey and Mr. Oxford called for 20 teeth in such a cutter, this was put at one end of the series, a Brown & Sharpe standard cutter with eight teeth came in the middle, and a four-tooth cutter was added to give an extreme condition of coarse spacing. A number of tests were also made with a 10-tooth cutter. Additional comparisons were made between the two 6-in. side milling-cutters, one of which had 12 teeth and the other 26 teeth, or two less than given by the formula mentioned above. The latter cutter was $^{15}/_{16}$ in. wide and the former 1 in., but otherwise they were exactly alike.

Other sets of cutters alike in every particular except the element to be studied were used in the tests to determine the effect of variations in spiral angle and rake angle. The sizes of these cutters are given in the discussion of the results.

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[3] Trans. Am.Soc.M.E., vol. 33 (1911), p. 245.

[4] The Art of Milling, Trans. Am.Soc.M.E., vol. 43 (1921), p. 549.

Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923. Slightly abridged.

Metal Used in the Tests

As the only object of the investigation was to compare cutters, mild steel was used in all the tests. This was done to enable the authors to make enough cuts to be sure of their results and to eliminate as far as possible variations due to lack of uniformity in the metal being cut. Fortunately most of the tests were made on blocks which were fairly uniform. The tabulation of the figures on the study of spiral angle, however, showed certain unexpected results occurring somewhat uniformly throughout the tests. A little later a cut was taken along the full length of the 18-in. block, the depth, feed, and speed being held constant throughout. The

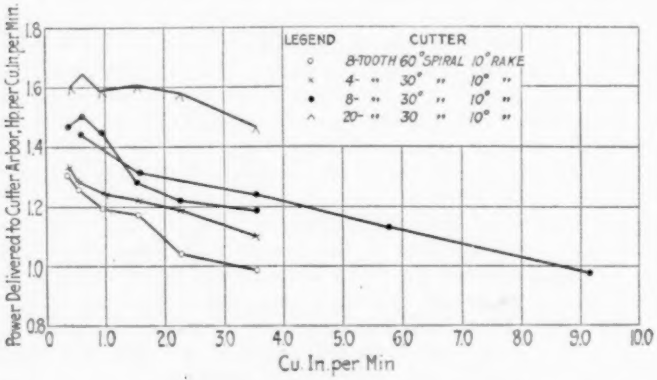

Fig. 1 Power Required By Coarse- and Fine-Tooth Cutters—Constant Depth of Cut and Variable Feed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.100 in.; cutting speed 94 ft. per min.)

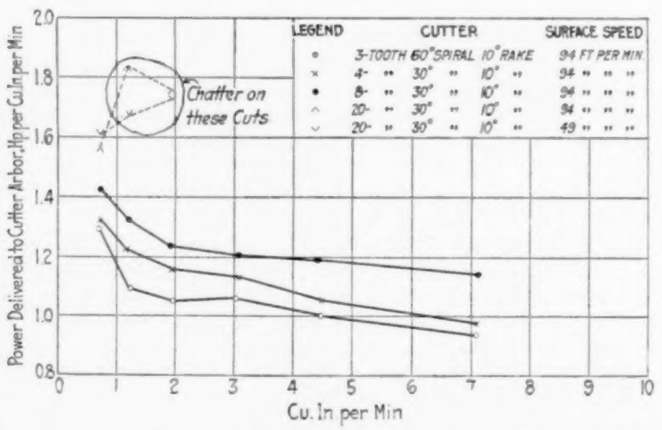

Fig. 2 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Constant Depth of Cut, and Variable Feed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.200 in.)

average power required was about six horsepower and the maximum variation was over seven per cent. A repetition of this cut gave the same variations at the same places, showing that it was not accidental. In the authors' studies enough tests had been made so that the average gave results which could be reasonably depended upon. However, this shows how much faith can be placed on the results of tests to determine small variations in power unless a considerable number of runs are made or unless steps are taken to eliminate the effect of these variations on the results.

The properties of the steel in all the specimens used in the tests were about the same with the exception of the 1/2-in. bar. The values for tests on specimens 0.505 in. in diameter and 2 in. long are given below:

	1/2-in. Bar	Other Specimens
Elastic limit, lb. per sq. in........	50,300	42,000
Breaking load, lb. per sq. in........	73,500	68,000
Elongation, per cent............	34	35
Reduction of area, per cent.......	62	62
Brinell hardness................	126	126

Method of Making Tests

A light cut was always taken along the specimen before starting any test to guarantee that the depth of cut would be constant. The table was then fed up the desired amount, and from two to six tests were made at this depth of cut in the 18 in. of length of the block. At the end of the first cut the table was run back and the depth of cut checked. The exact figure for the feed was determined by taking the time with a stop watch and measuring roughly the distance traveled with a steel scale and correcting this figure to the thousandth of an inch by reading the dial on the lead-screw handwheel. In this way the exact amount of metal removed per minute was determined.

The electrical instruments were carefully calibrated before starting the investigation and found to be practically correct over their whole range. Before and after each test, readings were taken to determine the friction load and several readings were made during the test to determine if the power remained constant. The differences between the readings under load and the no-load figures multiplied by the proper constants gave the horsepower delivered to the cutter arbor and to the table lead screw.

A number of tests were also made on a special fixture to measure horizontal and vertical pressures by use of two Kenerson traction dynamometers. This was mounted on the table of the machine and calibrated in position by the application of known weights. The method of making these tests was exactly the same as in the others

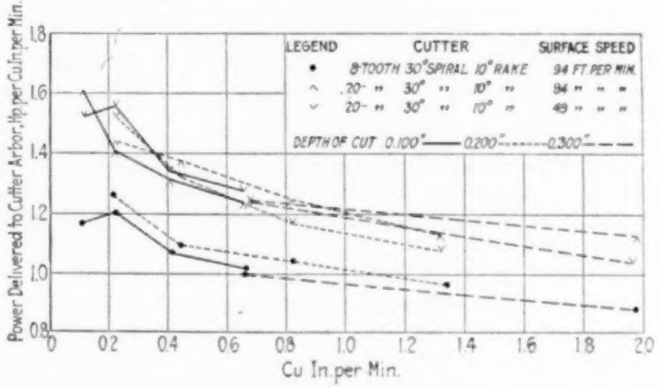

Fig. 3 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Variable Feed

(Material cut, mild steel; width of cut, 1.012 in.; depth of cut, 0.100 in. to 0.300 in. as indicated in figure.)

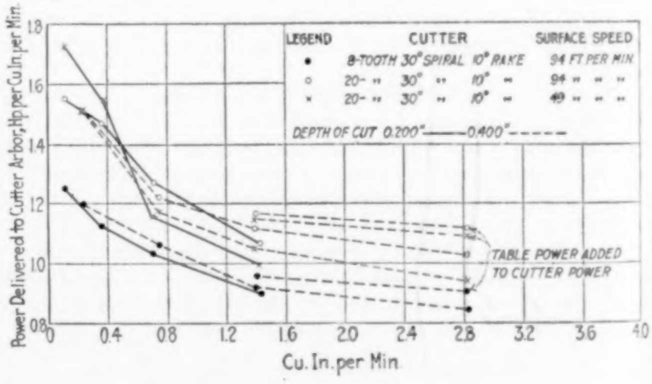

Fig. 4 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Variable Feed

(Material cut, mild steel; width of cut, 0.535 in.; depth of cut, 0.200 in. and 0.400 in. as indicated in figure.)

except that the reading of two dynamometers was added. For moderate cuts this apparatus combined in a high degree rigidity and accuracy, and gave some very interesting results.

As far as possible comparative tests on different cutters were made on the same block of steel and their order was arranged so that corresponding runs came as nearly as possible at similar positions on the the block. In this way errors due to lack of uniformity in the metal were reduced to a minimum.

The results are plotted in the form of curves having as one coordinate either horsepower per cubic inch per minute or pressure along the table. The former figure is used instead of the more common cubic inches per horsepower, as in some cases the sum of the cutter and table power is given as well as the cutter power

alone. For the other coördinate cubic inches per minute, feed per tooth, or maximum chip thickness are used. The latter quantity was used extensively in the paper by Professor Airey and Mr. Oxford, and they claim that the power required per cubic inch of metal per minute will be the same for the same maximum chip thickness for all cutters having similarly shaped teeth irrespective of the number of teeth.

Effect of Number of Teeth in Cutter

Several groups of tests were run in the studies of the effect of varying the number of teeth in the cutter. In the first group the speed and depth of cut were kept constant and the feed varied. This of course varied the chip per tooth and the output in cubic inches per minute and gave the comparison between cutters where equal finish is required for corresponding capacities. The second group contains tests where the feed and depth of cut were kept constant and the cutting speed varied. This gave a constant output and a variable chip per tooth. For the same feed per tooth the best surface finish is secured with the coarsest-tooth cutter. In the third group the depth of cut was kept constant and the cutting speed varied with the feed so as to give a constant chip per tooth. The output of course varied with the speed. This made a good study of the effect of the cutting speed on power requirements.

The tests in the first group are plotted in Figs. 1 to 4, each set

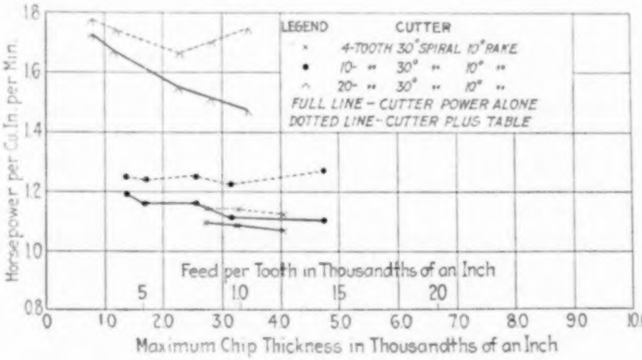

FIG. 5 POWER REQUIRED BY COARSE- AND FINE-TOOTH CUTTERS—CONSTANT FEED, CONSTANT DEPTH OF CUT, AND VARIABLE SPEED

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.100 in.; feed, 4.1 in. per. min.)

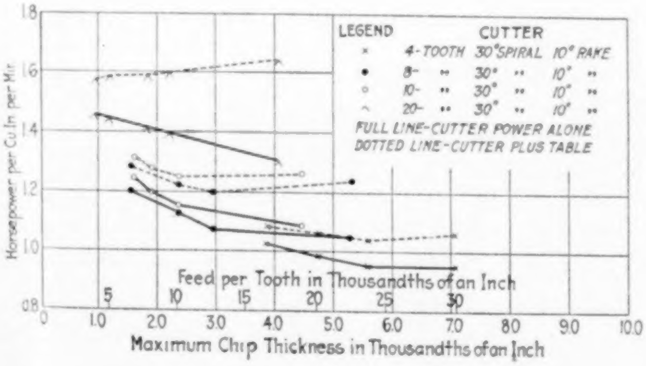

FIG. 6 POWER REQUIRED BY COARSE- AND FINE-TOOTH CUTTERS—CONSTANT FEED, CONSTANT DEPTH OF CUT, AND VARIABLE SPEED

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.; feed, 8.20 in. per min.)

of tests being made with a different width or depth of cut. These show that for the same cutting speed the cutter with the smaller number of teeth always takes less power and that this difference is more noticeable on wide cuts. Moreover the fine-tooth cutter gave considerable trouble from chatter on these cuts, especially when the depth was 0.200 in., where it was impossible to use it beyond a limited capacity. This shows that the width of the work is a necessary factor in the determination of the number of teeth in the cutter.

In a number of the tests plotted in Figs. 3 and 4 the fine-tooth cutter was run at approximately half the standard speed to see what effect this had on power consumption. When compared on the basis of cutter power alone, the slower speed showed a saving but not enough to bring it down to the coarse-tooth cutter. When the table power was added to the cutter power as was done in several tests in Fig. 4, the relative advantage of the slower cutting speed practically disappeared.

The real criterion of the effect of chip size on power requirements can best be determined from tests where the feed per tooth is variable but the output is constant. The second group of tests was carried on with this point in view and some of the results are plotted in Figs. 5 and 6. These show that the power efficiency is greater with coarser-tooth cutters even when compared on a chip-per-tooth basis and when only the power required by the cutter is

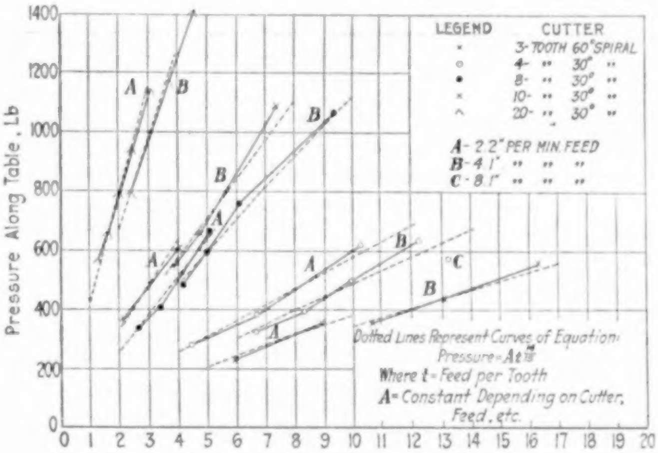

FIG. 7 EFFECT OF NUMBER OF TEETH IN CUTTER ON HORIZONTAL PRESSURE ALONG MILLING-MACHINE TABLE

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.)

considered. When the table power is added to the cutter power, the advantage of the coarse-tooth cutter is even more apparent.

An interesting point about these curves is that the sum of the cutter and table power comes to a minimum as the cutting speed is reduced, after which the table power increases more rapidly than the cutter power is reduced by the increased size of the chips. This point will be referred to again a little later.

Fig. 7 gives the results of a series of tests where the horizontal thrust along the table was measured at several different cutting speeds and two different outputs for each of five cutters. As the depth of cut was small, the power required by the cutter is practically equal to the product of the pressure multiplied by the velocity of the cutter. This checked rather closely with the amount determined from the wattmeter readings where these were taken.

The first point to be noted in this figure is that the pressure increases as the cutting speed is decreased to give a larger feed per tooth. Also if two cutters with different numbers of teeth are operated at the same total feed and also the same feed per tooth, the pressure caused by the cutter with the larger number of teeth is greater by a somewhat larger amount than given by the tooth ratio. The eight-tooth cutter is a little high on this basis, but this is due to the fact it was somewhat duller than the others. Machines and fixtures have limitations in the pressures for which they are designed, and this certainly limits the extent to which it is desirable to go in running fine-tooth cutters at slow speeds to give a large chip per tooth.

Another point of interest is that the curves for higher feeds all fall below those for lower feeds when plotted on a feed-per-tooth basis. The main difference between these tests is that the cutting speed is higher for the larger feeds. This raised a question as to the accuracy of the assumption often made that the cutting speed has no effect on the energy required per cubic inch of metal removed, and a special series of tests were made to study the effect of this variation. The results of these tests are presented a little later in the paper.

The data given in Fig. 7 were plotted on logarithmic cross-section paper and found to form a family of curves of the equation:

$$P = At^{14/18}$$

where P = horizontal pressure along table

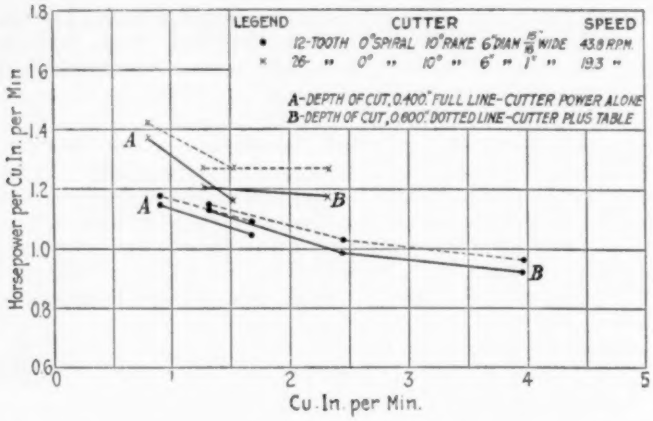

FIG. 8 POWER REQUIRED BY COARSE- AND FINE-TOOTH SIDE MILLING CUTTERS CUTTING MILD STEEL—CONSTANT SPEED, VARIABLE FEED

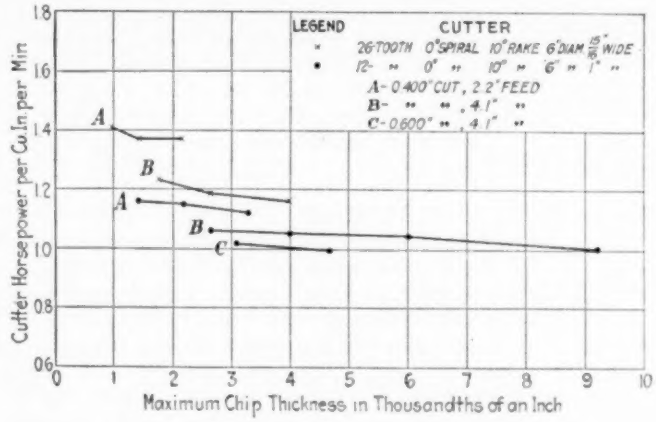

FIG. 9 POWER REQUIRED BY COARSE- AND FINE-TOOTH SIDE MILLING CUTTERS CUTTING MILD STEEL—CONSTANT SPEED, VARIABLE FEED

t = feed per tooth, and

A = a constant depending on cutter and feed.

Curves of this equation are plotted in Fig. 7 to show how they conform to the actual results. The number of tests involved is not sufficient to commit the authors absolutely to the power "$^{14}/_{15}$" but they feel sure that the correct figure is only a small amount below unity. In this connection it is interesting to note that the above figure is the one given by Frederick W. Taylor in his Art of Cutting Metals in the results of his experiments with lathe tools cutting mild steel.

Having an equation in the above form, it is possible to calculate for shallow cuts the proper relation of cutting speed and table feed to give the minimum power noted in the discussion of Figs. 5 and 6. Given—

V = cutting velocity in feet per minute

v = table velocity in feet per minute

E = efficiency of the table

$$\text{Horsepower} = \frac{P}{33000}\left(V + \frac{100\,v}{E}\right) \quad\ldots\ldots\ldots\ldots [1]$$

But $P = At^x$ and $t = Bv/V$, where B = a constant depending on the cutter. Substituting these values in [1] and solving for the value of V to make the power a minimum for any given feed and table efficiency,

$$V = \frac{100\,x}{(1-x)E}\,v \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

For example, if $x = {}^{14}/_{15}$ and E = 14 per cent, $V = 100v$.

Equation [2] gives a limit beyond which there is no saving in power when the cutting speed is lowered to give coarser chips per tooth.

Figs. 8 and 9 give the results of the studies with the side milling cutters. The two cutters were exactly alike except for the number of teeth and a slight variation in width. Fig. 8 shows tests where the cutting speeds were so arranged that the fine-tooth cutter took practically the same chip per tooth as the coarse-tooth on corresponding cuts. When compared on the basis of cutter power alone the coarse-tooth cutter was superior, and this advantage became still more pronounced when the table power was added. In attempting to carry the cut of 4 cu. in. per min. with the fine-tooth cutter the key in the arbor sheared, giving an illustration of the limitations of the machine in applying the chip-per-tooth theory.

Other series of tests with these cutters are shown in Fig. 9, the comparison being on a maximum-chip-thickness basis. Here again the fine-tooth cutter required more power and also proved inferior from the standpoint of chatter, as it was impossible to carry some cuts with it which were taken by the coarse-tooth cutter without a sign of distress.

Frequently in comparing results on a feed-per-tooth or a maximum-chip-thickness basis the power required per cubic inch per minute and the pressures along the table have been less for higher cutting speeds. The tests shown in Fig. 10 were therefore run to check up this relation. A set of cutting speeds and table feeds were arranged so as to keep the chip per tooth nearly constant as the cutting speed was increased. The power delivered to the cutter was taken from the wattmeter readings and checked by the horizontal-pressure figures. The results show that the horizontal pressure and the power required per cubic inch of metal per minute decreased as the cutting speed increased. The vertical pressure between cutter and work remained constant. In other words, if we compare removing 5 cu. in. per min. at 150 ft. per min. cutting speed with removing 1 cu. in. at 30 ft. per min. from the same place with the same cutter, the pressure tending to tear the piece from the fixture and the horsepower required per cubic inch will both be less in the first case. The explanation of this may be that the friction between cutter and work plays a much more important part in milling than in lathe work and that the coefficient of friction decreases as the speed increases.

It would doubtless seem from the foregoing that the efficiency of

FIG. 10 POWER AND VERTICAL PRESSURE—CONSTANT CHIP PER TOOTH AND VARIABLE LOAD

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.)

milling is increased by greater feeds per tooth. If these heavier chips are secured by using lower cutting speeds, the loss in the table becomes greater, the cutter itself requires more power per unit of metal than would be required for the same chip at higher speed, and the pressures between cutter and work become greater. The answer from the standpoint of power efficiency alone is then to use the cutter with the fewest possible teeth and to run it at higher speeds where the size of the chip is too great. The limitations to this practice are the danger of hammer or shock due to lack of continuity of cutting and the possibility of overheating the edges of the teeth due to the heavy pressures and high speeds. The structural strength of the tooth itself is not a limitation in well-designed cutters as this is practically always greater than the strength of the key or the arbor. The relation between the overheating of the edges of the teeth and the number of teeth in the cutter can only be settled by judgment, as no work has been done on the relative effect of cutting speed, volume and length of chip, ductility of the

(Continued on page 205)

The Elasticity of Pipe Bends

By SABIN CROCKER[1] and S. S. SANFORD,[2] DETROIT, MICH.

In this paper the authors develop in detail mathematical formulas connecting the deflection of different types of pipe bends with the force producing deflection, and also expressing the stress set up as a function of the observed deflection and the constants of the bend. They describe experiments made to check force vs. displacement, and present charts for use in selecting the proper size and shape of bends to take care of a given expansion, and to determine the force exerted by a bend when in a given state of deflection. In general they recommend bends of larger dimensions than are ordinarily used, and their figures are said to be on the side of safety. In some cases the bends tested showed a greater flexibility than anticipated, due to minute folds formed on the compression side when bending pipe to short radius.

THE use of expansion loops, offsets in the line, right-angled turns and similar devices to furnish flexibility for expansion and contraction in pipe lines resulting from temperature changes, has been general practice for years. Such bends, which utilize the elasticity of the pipe itself, are very commonly used for high-pressure work in preference to slip joints, corrugated expansion joints, or swivel offsets in which screwed elbows are arranged to turn on pipe threads. The use of pipe bends reduces internal friction in the piping by providing easy turns, eliminates unnecessary fittings and joints, and facilitates clearing other pipes and structural interferences.

Up to the present time the disposal of expansion and contraction in power-plant piping has been largely a matter of judgment rather than of rational calculation on the part of the designer. This has been due to a general lack of knowledge or interest regarding the principles and methods involved in calculating the forces and stresses resulting from the expansion of piping. However, if certain rather fundamental principles of engineering mechanics are brought into play, it is usually possible to determine numerical values with fair accuracy during the progress of design, and make use of this knowledge to improve the piping layout. As the drift toward higher steam pressures and temperatures in turbine practice continues, the problem becomes more and more important. Since there is also a tendency for the steam turbine to grow smaller relative to the size of the steam line to which it is connected, there is a danger that excessive stresses will be set up in the turbine casing as a result of expansion in the pipe line unless the piping designer knows how to calculate the forces involved.

The amount of expansion to be cared for in a pipe line can be accurately computed, provided the temperature range between extreme hot and cold conditions, the length of pipe, and the coefficient of expansion for the material are known. Having computed the amount of expansion or elongation of the pipe, the problem resolves itself into determining whether the piping arrangement under consideration has sufficient "spring" to absorb this elongation without producing either undue fiber stress in the material or excessive forces tending to tear the piping loose from its anchors. At the same time the proportions of the line must be economical and be adjusted to clear any structural interferences in the plant. Wall thickness and diameter of pipe, radius of curvature, and general layout all affect the flexibility which can be obtained with a given run of pipe.

The inadequacy of the usual methods of steam-pipe design has been brought forcibly to the attention of The Detroit Edison Company by several minor mishaps during the past few years. Fortunately, none of these were of a serious nature, but they did serve to show that piping laid out according to the best modern practice may be subject to forces of unexpected proportions. Thus in one instance unexpectedly large reactions caused a 14-in. high-pressure steam main to tear loose from what was supposed to be an adequate anchorage. This incident, and others of a somewhat similar nature, led those responsible for design and operation to ask themselves whether such failures could not be avoided by more intelligent design. Consequently, in undertaking the design of the company's Marysville power plant, where the elongation per hundred feet of steam pipe amounts to almost seven inches and the steam pressure is 300 lb. per sq. in,, it was decided that pipe expansion must be cared for in a rational manner if such a thing were possible. Accordingly, the investigation here reported was undertaken to determine the fundamental relations between deflection, force resisting deflection, and stress set up in expansion pipe bends of various shapes. These relations were first determined mathematically, and later checked by physically testing bends of shapes which readily lent themselves to measurement of the quantities involved. The results thus obtained were then applied to the more complicated conditions in actual pipe lines. As a result it was possible to design the piping layout for the first section of the Marysville power plant, which has just been put in operation, so that the following results are obtained without allowance for cold springing:

Maximum fiber stress in pipe wall.....	6900 lb. per sq. in.
Maximum thrust against pipe anchorage	680 lb.
Maximum thrust against turbine flange	580 lb.

If credit is taken for cold springing, the maximum stress and forces given above are further reduced. These values have been obtained without making the expansion bends unnecessarily large.

Previous Work by Others

Before proceeding along independent lines an extensive search was made for existing literature, which disclosed that very little had been written on the subject. However, the following articles are of special interest:

(*A*) Formoenderung und Beanspruchung federnder Ausgleichroehren Strains and Stresses in Expansion Bends), by Prof. A. Bantlin, *Zeitschrift des Vereines deutscher Ingenieure*, Jan. 8, 1910, p. 43.

(*B*) Expansion of Pipes, by Ralph C. Taggart, *Trans.Am.Soc.C.E.*, paper No. 1167, Dec., 1910.

(*C*) Elasticity and Endurance of Steam Pipes, by C. E. Stromeyer, *Engineering*, June 19, 1914, p. 857 (from a paper read before the Institution of Naval Architects).

(*D*) Pipe Bends, Their Growing Use and Efficacy, *The Valve World*, Oct., 1915 (published by Crane Co.).

(*E*) The Design of Pipe Bends for Expansion in Pipe Lines, by J. G. Stewart, *Power*, May 10, 1921, p. 742.

Reference (*A*) deals with the comparison of physical tests and calculated results for bends similar to our double-offset expansion U-bends.

Reference (*B*) treats principally of the use of straight pipe and fittings in making up expansion loops. The results are in general similar to those of the present authors for straight lengths of pipe.

Reference (*C*) describes a series of failures of steam pipes in service, due to repeated strains beyond the elastic limit. A set of formulas similar to those presented in this paper was worked out to show what elongations could be cared for without eventually producing failure.

Reference (*D*) is a report of physical tests on pipe bends made by the Mechanical Experts Department of Crane Company, and published in their organization paper, *The Valve World*. A series of curves deduced from their experimental data and giving the amount of expansion required to produce a fiber stress of 15,000 lb. per sq. in. in different-shaped bends was included for the use of those interested in pipe design.

Reference (*E*) gives a method of computing fiber stress similar to that of Reference (*C*), and a chart for reading the elongation corresponding to 15,000 lb. per sq. in. stress for different bends.

It is worth comment that while the author's formulas were worked out independently of Reference (*C*) and before Reference (*E*) was published, all three sets are practically identical. The comparison of theoretical formulas with actual test results, and the rather complete design graphs worked out in this paper, take the subject a step beyond the point reached by earlier publications. The fact that none of the previous investigators has published all of the mathematical steps leading up to his final formulas, will make the derivations given in the complete paper by the authors of special interest to any one having occasion to work with the formulas.

[1] Piping Engineer, Detroit Edison Co., Assoc-Mem. Am.Soc.M.E.
[2] Research Department, Detroit Edison Co., Jun.Am.Soc.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Table 1 is a summary of such data published in the above references as were in shape to reduce to a common form for comparison with the work of the present authors. It will be noted that the formulas of References (*C*) and (*E*) agree very closely with those of this paper, while Reference (*D*), which has been widely quoted during the past seven years, differs considerably from the others except for the double-offset expansion U-bend. The following extract is quoted from Reference (*D*):

> A 180-deg. or U-bend has twice the expansive value of a 90-deg. or quarter-bend of the same size and radius, and an expansion U-bend, four times the expansive value of a quarter-bend or twice that of a U-bend. A double-offset expansion U-bend has five times the expansive value of a quarter-bend, two and one-half times that of a U-bend, and one and one-fourth times that of an expansion U-bend.

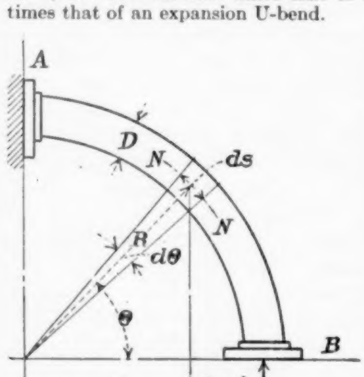

Fig. 1 Quarter-Bend, Force Axial

In other words, the relative ability of these particular bends to take up expansion without exceeding a safe stress is stated by Reference (*D*) to be in the ratio of 1 : 2 : 4 : 5, while the calculated ratio given by References (*C*) and (*E*), and checked by the present authors, is 1 : 4.4 : 13.2 : 32.9, assuming that the quarter-bend is connected to the pipe line so that the thrust of the line acts along the axis of the pipe in the bend at the joint, as shown in Fig. 1.

Referring to the stress index of Table 1, Reference (*D*) agrees quite closely with the others' results for double-offset expansion U-bends, but gives much higher values for the expansion cared for by quarter-bends, U-bends, and expansion U-bends than do the others. It will also be noted that the stress and flexibility indexes for the double-offset expansion U-bend given by reference (*E*) differ slightly from those given by the present authors. This is because the two bends considered are not of exactly the same shape.

A peculiarity of bends noted in Reference (*A*) was also observed in some of the bends tested by the authors, i.e., that the elasticity found by test exceeded the computed elasticity. Reference (*A*) describes tests on three kinds of bends formed to a shape which resembles a double-offset expansion U-bend, the first variety being bent from solid rod stock, the second from steel pipe, while the third was a hollow iron casting similar to a pipe bend. Tests of the first and third varieties checked very closely with calculated results, while the bend fabricated from a straight length of pipe was found to be much more elastic than the calculations indicated. The explanation given in Reference (*A*) is that the large deflections of the steel pipes must be attributed chiefly to waves or folds upon the compressed side of the pipe.

This conclusion is supported by the results presented here, all of the test bends formed to a radius of five pipe diameters or less having a flexibility in excess of calculated values, while, with one exception, those formed to a radius of six diameters or more gave results agreeing closely with those obtained by the formulas. This would seem to indicate that the excessive elasticity was due to puckers or folds in the pipe wall produced in the process of bending, the tendency being to thin the pipe wall at the outer circumfer-

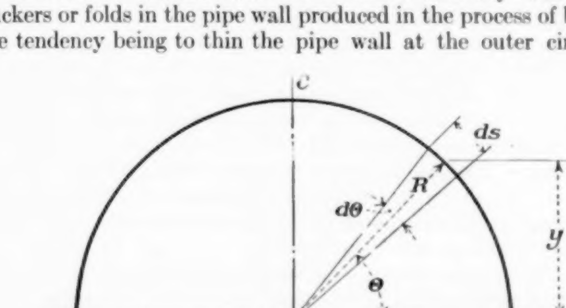

Fig. 2 Plain U-Bend

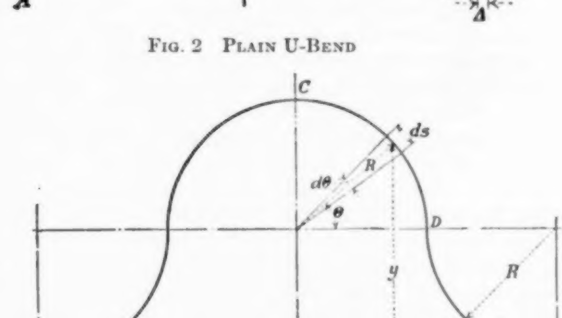

Fig. 3 Expansion U-Bend

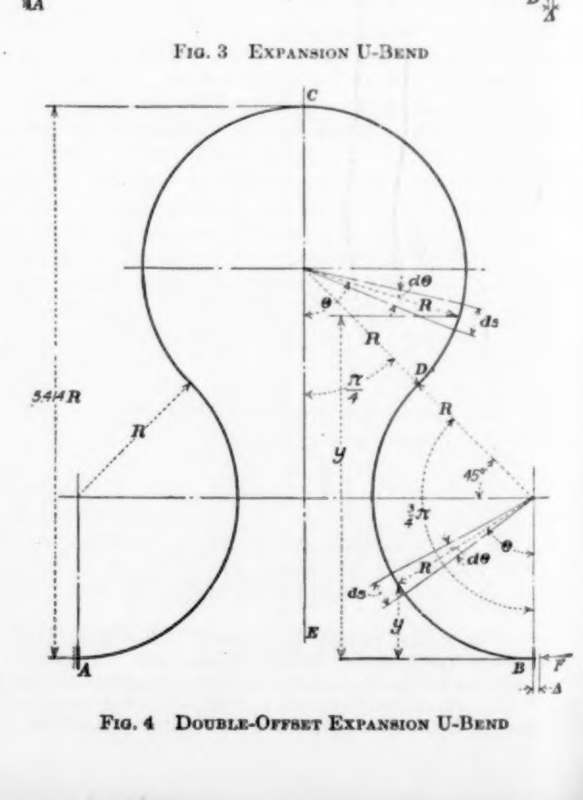

Fig. 4 Double-Offset Expansion U-Bend

TABLE 1 SUMMARY OF DATA ON PIPE BENDS

Reference	C = Stress Index; C, in $S = C\frac{D\,\Delta\,E}{R^2}$				K = Flexibility Index; K, in $\Delta = K\frac{FR^3}{EI}$			
	Quarter bend	U-bend	Expansion U-bend	Double-offset expansion U-bend	Quarter bend	U-bend	Expansion U-bend	Double offset expansion U-bend
(*C*) C. E. Stromeyer[1] . .	1.404	0.318	0.106	0.0495	0.356	1.571	9.426	34.54
(*D*) Crane Co.[2]	0.2	0.1	0.05	0.04	—	—	—	—
(*E*) J. G. Stewart[1]	1.404	0.318	0.106	0.045	0.356	1.571	9.42	37.9
Crocker & Sanford, Calculated	1.404	0.318	0.106	0.0427	0.356	1.571	9.42	39.88
Crocker & Sanford, Test	—	—	0.048 to 0.106	0.042 to 0.0427	—	—	9.42 to 20.8	39.9 to 40.7

Definitions of Symbols

C = stress index (numerical values given in left half of table).
K = flexibility index (numerical values given in right half of table).
S = maximum bending stress in pipe wall, lb. per sq. in.
D = outside diameter of pipe, in.
R = mean radius to which bend is formed, in.
E = modulus of elasticity (30,000,000 lb. per sq. in. for steel).
I = moment of inertia of section, taken normal to center line of pipe of which bend is formed, in.^{4}
F = forc causing deflection of bend, lb.
Δ = deflection of flange of bend = elongation of pipe line due to change in temperature, in.
= totel expansion to be absorbed by bend, i.e., total expansion calculated for a straight run of pipa with length equal to distance between anchors which occur nearest to bend under consideration.

[1] For references, see previous paragraphs.
[2] Formulas deduced from curves published in *The Valve World*, Oct., 1915
For shape of bends see Figs. 1, 2, 3, and 4.

ence of the bend and form minute crinkles or waves at the inner circumference. These conditions are more pronounced the shorter the radius of curvature, and in the case of the bend described in Reference (A), which was bent to a radius of only three to four pipe diameters, the waves were plainly visible. In American practice, where the minimum allowable radius of curvature is limited to five or six pipe diameters, these waves are not so visibly evident, nevertheless we may assume that they are present and have the effect of increasing the flexibility of bends formed to too short a radius.

Formulas and Design Graphs

A pipe bend may be considered as a beam of special form, one end of which is fixed and the other end of which is free to move in the direction of a force acting upon it. Since the bend is an elastic body, the movement of its free end will be proportional to the force acting, within the elastic limit of the material.

In the complete paper expressions are derived for the deflection Δ and the maximum bending stress S for the quarter-bend (Fig. 1), the U-bend (Fig. 2), the expansion U-bend (Fig. 3), and the double-offset expansion U-bend (Fig. 4), which are given in Table 1.

In each case, flange A has been considered as fixed. Such a condition would exist if the line to which A is connected where anchored at that point, or if A were a flange at the turbine. As a matter of fact, the entire analysis is really based on the movement of flange B with respect to A, and it makes no difference whether A is actually fixed or is permitted to move. F is the net force with which the pipe line pushes against the flange B when the line is hot. For design purposes the total expansion to be cared for between anchorages is determined from known or assumed temperatures, length of pipe, and coefficient of linear expansion. The length of pipe used is a nominal length equal to the actual linear distance between anchorages. In effect, it is as though a line of pipe such as that shown in Fig. 5 were assumed to be like that in Fig. 6, with the total movement due to the expansion of a straight pipe of length L applied at the flange B.

For the convenience of the power-plant designer, the formulas for several of the standard bends are represented graphically in Figs. 7, 8, and 9. The bends considered are the quarter-bend, U-bend, expansion U-bend, and the double-offset expansion U-bend with the forces applied as shown in the small figures on the graph and corresponding to Figs. 1, 2, 3, and 4. The forces and stresses set up in bends made up of pipe sizes up to and including 20 in., and bent to radii up to and including 120 in., may be read from these graphs without the necessity of solving the formulas.

Fig. 7 gives the maximum bending stress in the pipe wall of the bend for any expansion in the pipe line which must be cared for. Inasmuch as the stress is proportional to the outside diameter of the pipe for any given value of Δ, and is independent of its weight, this diagram serves for all weights of pipe. This diagram is drawn up for 8-in. pipe and values for that size may be read directly. For instance, an 8-in. expansion U-bend, formed to a radius of 60 in. and required to take up an expansion of 0.7 in. in the pipe line, would have a maximum bending stress set up in it of 5380 lb. per sq. in.

A sample problem will indicate the method to be used for other sizes of pipe. Since the stress is proportional to the diameter of the pipe, the value of the stress for any size of pipe may be obtained after finding the stress in an 8-in. pipe. The proportion between stresses can be made directly on the diagram by following the radial lines diverging from its lower right corner.

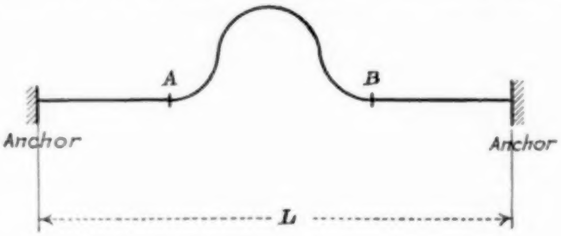

Fig. 5 Actual Piping Layout

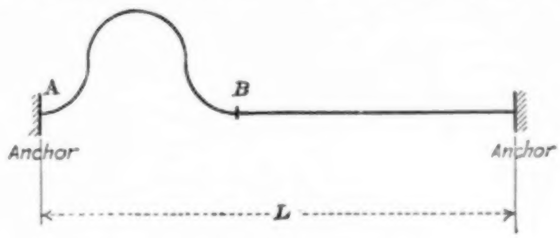

Fig. 6 Layout as Assumed for Calculation

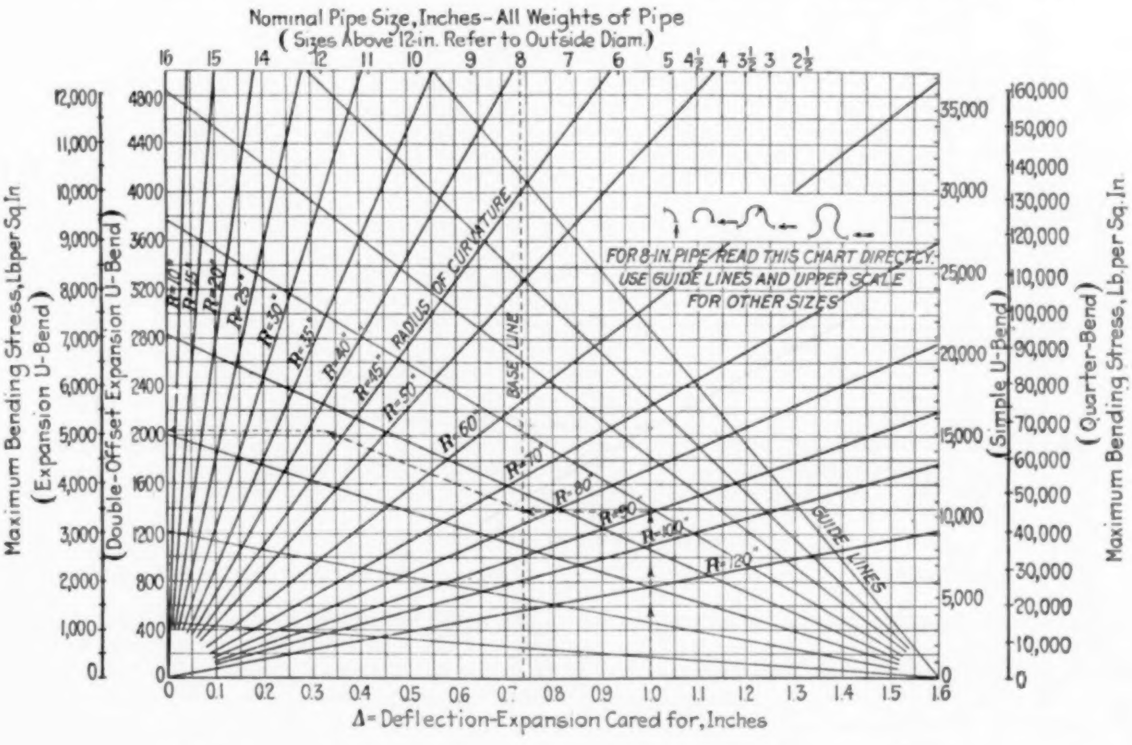

Fig. 7 Stress vs. Displacement for Various Shapes and Sizes of Pipe Bends

Sample Problem: A 12-in. double-offset expansion U-bend having a radius of 90 in. is to take up an expansion of 1 in. Required, the maximum bending stress in the bend.

From the intersection of Δ = 1 in. and R = 90 in., extend horizontally to the vertical line under 8-in. pipe, which is referred to as the "base line," and the obliquely (with a line passing through lower right-hand corner) until under 12-in. pipe on the upper scale. The result is 2040 lb. per sq. in.

Since the stress is directly proportional to the displacement, this diagram may be used for values of Δ which fall beyond its range by multiplying both stress and displacement scales by the same factor. For instance, if a 5-in. expansion is to be considered, the stress for an expansion of 1 in. should be read on the graph and multiplied by 5.

Figs. 8 and 9 give the forces set up in the pipe line when pipe bends are used to take up the expansion. As these relations are functions of the moments of inertia of the pipe sections the internal diameters affect the results, and Fig. 8 has been drawn for "standard weight" and Fig. 9 for "extra heavy" pipe. These diagrams are for 16-in. pipe and values for this size may be read directly. The scale of pipe sizes at the top of diagram is laid off according to the moment of inertia of the pipe section, as the force to produce a given base line under 16-in. pipe, for making the proportion. The solution for a sample problem is indicated by the dash lines in Fig. 8. A double-offset expansion U-bend made of 14-in. O.D. pipe, $^3/_8$ in. thick, formed to a radius of 80 in., is required to take up the expansion of 1.1 in. in the pipe line. From the diagram, the force acting against the pipe anchorage is 610 lb.

Since the force is directly proportional to the displacement, these diagrams also may be used for values which fall beyond their range by considering both force and displacement scales as multiplied by the same factor. It should be noted that in using these diagrams the pipe size refers to the size of pipe used in the bend and has nothing to do with the size of pipe in the rest of the line.

Results of Tests

In all, eight separate expansion bends were tested. The methods employed in testing are described in the complete paper. The results are given in condensed form in Table 2.

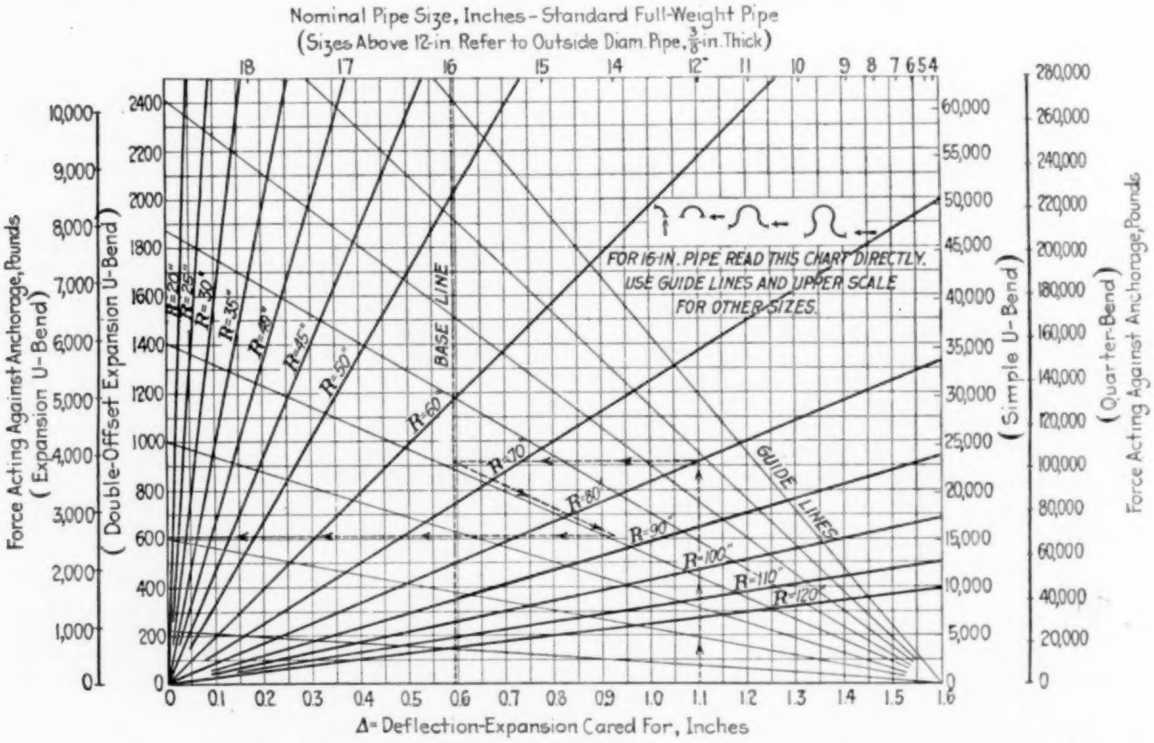

Fig. 8 Displacement vs. Force Exerted or Various Shapes and Sizes of Pipe Bends—Standard Pipe

deflection in the bend is proportional not to the diameter, but to the moment of inertia of the pipe.

After finding the force existing for a given deflection in the 16-in. pipe, the value for any other size of pipe may be obtained by using the radial lines diverging from the lower right corner, and the vertical

As noted before, the results from bends formed to a radius greater than 5 pipe diameters agree closely with those obtained from the formulas with one exception, this exception being the 10-in. expansion U-bend. The radius in this case was 6 diameters. The pipe in this bend was the largest size tested, all others being 6-in. or smaller. It is relatively more difficult to bend large pipe than small pipe, so as the pipe size increases the minimum allowable radius (expressed in pipe diameters) also has to be increased. One American manufacturer states that the shortest radius to which a 22-in. standard pipe can be bent is 6 diameters, while a 5-in. pipe can be bent to 4 diameters. In other words, there is relatively greater danger of the pipe buckling or having waves and folds in it in the larger sizes. It is entirely possible that these are responsible for the unexpected flexibility in this 10-in. bend. The bend was too large to be made from one length of pipe, so it was welded at the top of the loop. The bend was one purchased especially for test and had not seen service.

The first 6-in. expansion U-bend in Table 2 was one purchased especially for test and had not previously seen service. In this case there is a very satisfactory agreement between test and formula.

The remaining three 6-in. expansion U-bends were bought for the auxiliary superheated-steam line at the

TABLE 2 RESULTS OF TESTS BY AUTHORS ON EXPANSION BENDS

Type of U-Bend	Nominal size of pipe, in.	Measured thickness of pipe, in.	Radius of bend, in terms of nominal pipe diameter D	Flexibility index[1] K	
				Calculated	Observed
Expansion U-bend	10	0.336	6D	9.42	20.8
Expansion U-bend	6	0.418	6D	9.42	9.42
Expansion U-bend	6	0.27	5D	9.42	14.08
Expansion U-bend	6	0.274	5D	9.42	16.88
Expansion U-bend	6	0.285	5D	9.42	12.02
Double-offset exp. U-bend	6	0.41	6D	39.88	39.9
Double-offset exp. U-bend	4	0.237	7D	39.88	40.7
Expansion U-bend	3-1/4-in. boiler tube	0.12	8.31D	9.42	9.42

[1] In formulas in Table 1

Connors Creek power house and had not seen service at the time of the test. All were formed to a radius of 5 diameters and all had a flexibility in excess of the calculated value.

The two double-offset expansion U-bends were purchased especially for test and had a flexibility agreeing closely with the calculated values.

In order to eliminate as much as possible the formation of waves or folds in the pipe during the bending operation, a $3^1/_4$-in. expansion U-bend was made up from a straight boiler tube in a Babcock and Wilcox boiler-tube-bending machine. In this machine one end of the tube is clamped to one end of a quadrant having a grooved face and a radius of 27 in. This quadrant turns on its axis and is geared to a motor, the tube sliding against a stationary grooved wheel on the machine as the quadrant is turned. The length of the tangent from the grooved wheel to the circumference of the quadrant is relatively short. A second grooved wheel on the end of a lever which is pivoted near the axis of the quadrant assists in the bending. In this way compression on the inner side of the bend is minimized, reducing the danger of having waves or folds formed in the tube. The bend was formed cold in this machine, as nearly as possible to shape, and then removed and heated where necessary, and the bending operation completed. The test results show a very close agreement with calculated values. It should be noted that the radius of the bend with respect to the diameter of the pipe is greater than with any of the other bends tested. This tends to bear out the theory that those bends which are more flexible than the formula would indicate, owe their extra flexibility to waves formed on the compression side of the bend when a pipe is bent to a short radius.

Attention is called to the fact that in no case did the tests show a bend to be less flexible than the formulas would indicate, so if the formulas and the design graphs presented in this paper are used in practice, the designer will always be on the safe side. His bends may or may not be more flexible than his calculations would indicate, depending upon how the bends were made, but he need not fear that forces or stresses in excess of his calculated values will exist.

All the bends were tested while cold. Since the physical properties of mild steel are not altered appreciably up to 700 or 750 deg. fahr., which are about the maximum temperatures to be expected in a steam line with present practice, the relation between force and deflection should be the same whether the pipe is hot or cold.

The test method used was a rather crude one, yet in several cases the agreement between calculated and test values is remarkably close. It will be noted that in some cases there is a tendency for the force to become disproportionately larger as the displacement increases. This was doubtless due to the binding of the jack as the flange tended to swing to one side, and the flanges to assume positions at an angle to the pipe line. It should also be noted that in deriving the formulas no allowance was made for a change in shape of the bends as they take up expansion. Actually, the height of the bend, and therefore its flexibility, increases as the bend is deformed, so that for large deflections the actual force will be less than the calculated force. However, as the deflections are relatively small in actual practice, this will not affect the results seriously.

In checking a piping layout to determine if excessive fiber stresses exist anywhere in the pipe wall, the longitudinal bursting stress due to the pressure of the steam should be added to the bending stress given by the formulas. This is especially important when working with high steam pressures.

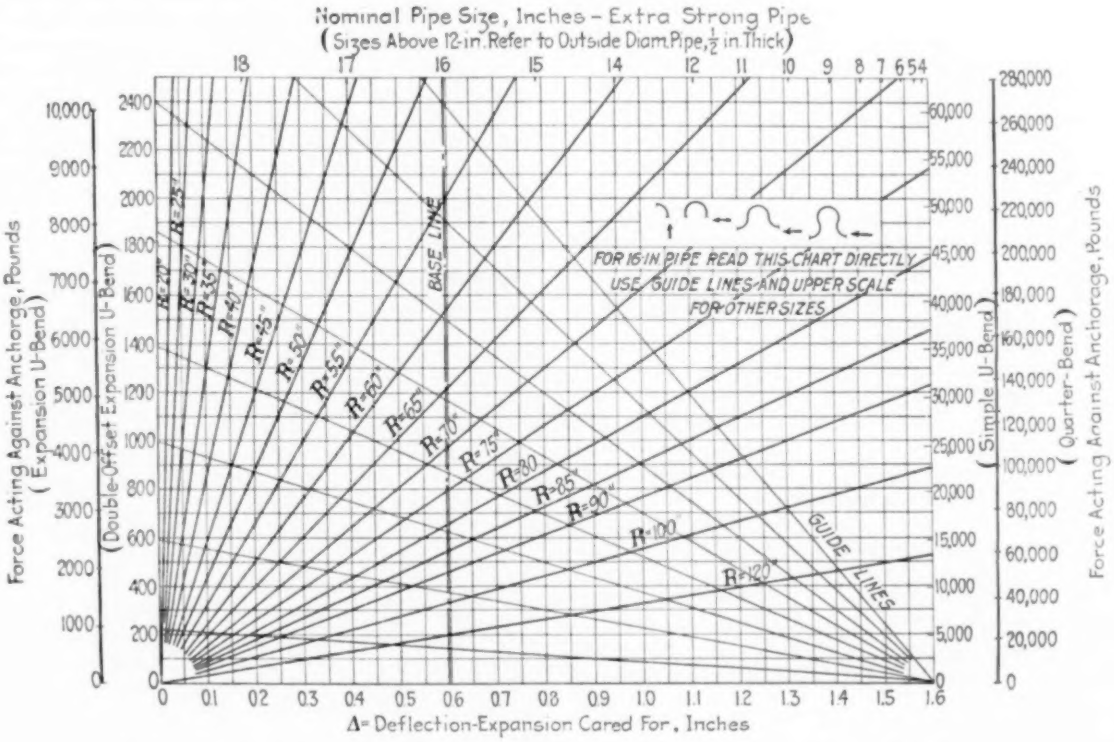

Fig. 9 Displacement vs. Force Exerted on Various Shapes and Sizes of Pipe Bends

Nothing has been said about the expansion which can be compressed back into the pipe by the forces set up at the anchorages. In each case it has been assumed that the expansion bend takes care of all of the expansion and that none of it is compressed back into the straight pipe. Actually, of course, a small part of the expansion is taken up by compression, the amount being directly proportional to the length of the pipe and to the force set up, and inversely proportional to the cross-sectional area of the metal in the pipe and to the modulus of elasticity for that metal. In the case of expansion U-bends and double-offset expansion U-bends, which are very flexible, the amount of expansion compressed back into the pipe is so small compared to the amount taken up by the bend that it can be neglected altogether. In the case of U-bends and quarter-bends, however, the forces are larger and consequently more of the expansion is taken up by compression. In actual practice the amount taken up by compression may be neglected, for in doing so the designer is making a small allowance on the side of safety.

Summary

To summarize in closing: This paper treats of expansion bends in pipe lines as if they were beams acted on by the forces set up by expansion of the piping. Upon this basis formulas have been derived for the forces and stresses in some of the more common types of bends. In the light of the material presented in this paper the

limits of safe expansion values for pipe bends set by Reference (*D*), and commonly quoted in engineering texts and handbooks, are apparently correct only for the double-offset expansion U-bend. For the other shapes the published values are much in excess of those given here. It is the authors' contention that these limits should be revised to agree with the formulas presented in this paper, for unless the published tables are used with large factors of safety, the forces and stresses existing in pipe lines will be excessive and dangerous.

Discussion

The discussion was opened by the reading of a contribution from William B. Campbell[1] who wrote that the right-hand half of the authors' Table 1 gave data for direct comparison of the calculated relations between force F acting on the bend and the deflection Δ produced, and the same relation from actual test. It would appear, however, that the left-hand portion was semi-experimental, in that the calculated values showed a relation deduced analytically between the observed deflection Δ and the maximum fiber stress S was manifestly not observed directly, but was inferred from the experimental value of F which accompanies a given Δ. This method of course reflected the observed relation between deflection and force acting, but it did not eliminate the effect of the method used for calculating S from F, which was based on ideal conditions in the shape and physical dimensions of the pipe. For this reason the "experimental" data in this section were not so conclusive as those in the right-hand section.

Robert Cramer[2] said that it was gratifying to learn that the authors had made an attempt to compare directly theoretical and experimental results. He noted in the paper, however, a point of theoretical nature which should be considered when test results were incorporated. In the diagram giving the basis of the theoretical investigation, the neutral axis of the cross-section of the bend was assumed to pass through the center of the circle, which was not true in the case of a pipe bend. It was a well-known fact, he said, that the neutral axis in curved beams did not pass through the center of gravity of the cross-section as it did in straight beams, and the peculiarity was more pronounced the shorter the radius of the beam compared with the magnitude of the cross-section.

For this reason, he said, it would pay the authors to pursue a line of more rigid theoretical investigation of the deviation of the experimental results from the theoretical results in the case of the shorter bends. He had noted in making comparison between the experimental and calculated results that in some cases the two checked closely, while in others the variation was very marked. It was not the slight variation to be expected from experimental or observational errors, but one which would suggest that the authors should look for some error in their calculations.

The authors considered the deflecting force always to be at right angles to the flange on which it was applied, with the exception of the case of the quarter-bend, in which they had distinguished between two cases, one with the force acting at right angles to the flange and the other with a force acting in the plane of the flange. In the actual case, he said, the problem was really more complicated than would appear from the authors' investigation, as it was frequently necessary to twist the flange in order to make a tight joint, and this involved another source of strain.

Francis Hodgkinson[3] said that the paper was extremely valuable because more and more attention must be given to the very important subject of the flexibility of the steam line. This was the first time, he thought, that reliable information had been presented. Generally speaking, he said, flexibility could be secured by laying out straight runs of pipe at right angles to each other. There was another kind of flexibility which the paper did not mention, and which was torsional flexibility of the pipe. With the decrease in size of turbines and the increase in capacity, the structure of the pipe line was becoming almost as strong as the structure of the turbine itself and it was necessary for the flange to have some angular freedom and that the pipe be arranged in such a way that its whole length would not have to be lifted up because of lack of alignment.

[1] Rutgers College, New Brunswick, N. J. Assoc-Mem. Am.Soc.M.E.
[2] Cons. Engr., Milwaukee, Wis. Mem. Am.Soc.M.E.
[3] Chief Engr., Westinghouse Elec. & Mfg. Co., S. Philadelphia, Pa. Mem. Am.Soc.M.E.

It was frequently necessary, he said, to have some length of pipe with torsional flexibility.

J. A. Freiday,[1] speaking as a representative of Thomas E. Murray Inc., said that they considered the paper a valuable contribution, bearing as it did upon a subject which had not always been given proper consideration in the past. The subject was one which they had carefully considered in the numerous power stations they had designed. Up to two or three years ago they had made use of expansion loops made of pipe bends similar to those described in the paper. In a few cases, he said, they had experienced trouble with bends which evidently had not been properly annealed and which showed a tendency to straighten out and grow after being placed in service. In one case the growth of a 14-in. 90-deg. bend exceeded 2 in. in a few months, the increase being measured after the pipe had been taken out of the line.

In order to eliminate the possibility of such distortion and also to take care of the increasing steam temperatures in larger steam lines required by larger modern units, they had made an investigation some time ago to determine the best method of providing for expansion with the least reaction at the point of anchorage. The result of the investigation, he said, had shown that loops corresponding to the expansion U-bends but made up of straight pipe and fittings produced less reaction than an expansion U-bend requiring the same space.

This method of taking care of bends, he said, lent itself particularly to large pipe, for the use of large expansion U-bends was not practical due to fabrication difficulties. With the design of loop they had used in all recent installations no excessive pressure drop had been encountered due to this method of making bends.

He asked the authors if they had investigated any loops designed as he had described.

H. Leroy Whitney[2] said he had noticed many examples of square-bends and U-bends which did not take up the expansion they had been figured for and also, particularly in long transmission lines, he had noticed a double expansion U-bend which had taken over twice the expansion figured for it and that over a period of years marked deterioration in the pipe was shown. In regard to the buckling of pipe on the inside of the bend, he said that it was perfectly evident that if the pipe did buckle on the inside the fibers on the outside were not stressed nearly as much as if the pipe did not buckle. In large bends of comparatively small thickness it was almost impossible to make the U-bend without buckles on the inside. The buckles did no harm, he thought, they did not retard the flow of steam through the pipe to any appreciable extent but did take up expansion. If the pipe was subject to very high vibrations, he said, it was sometimes customary to pull or push them to the full extent that they would be distorted by expansion, so that when they were hot they would be in their normal state, relieving the thrust on steam apparatus.

George A. Orrok[3] said that he understood all the research had been made with cold pipe without pressure on the inside. He wondered if there was any difference between the action of a pipe bend with two or three hundred pounds pressure on the inside and one which was cold. He said that he thought many pipe bends had been designed so that the metal had been stressed beyond the elastic limit. It was a well-known fact that a pipe should not be stressed to 5500 or 6000 lb. This made it necessary to use heavy pipe if the pipes are large. Many times a pipe would rupture at bends when the weld had been placed in the neutral axis. He thought very heavy pipe should not be placed in bends and suggested the use of seamless tubing which was a common practice in our Navy and in the new stations of England and the continent. Such tubing could be stressed up to 12,000 lb.

John A. Stevens[4] asked what would be the thrust from pipe lines with a temperature of about 750 deg., at which the pipe itself would be red hot, and whether there would be a sufficient amount of deformation in the pipe line and the fittings so that the actual thrust would be smaller.

[1] Mech. Engr., Thos. E. Murray, Inc., New York, N. Y. Mem. Am.Soc.M.E.
[2] Director and Sales Engr., The M. W. Kellogg Co., New York, N. Y. Mem. Am.Soc.M.E.
[3] Cons. Engr., New York, N. Y. Mem. Am.Soc.M.E.
[4] Cons. Engr., Lowell, Mass. Mem. Am.Soc.M.E.

Progress in Steam Research

Harvard Investigation in Joule-Thomson Effect Shows First Results—Work Well Started at Massachusetts Institute of Technology and U. S. Bureau of Standards—A.S.M.E. Annual Meeting Session Devoted to Reports and Comments on Progress

ON JUNE 23, 1921 a group of scientists and engineers met in Cambridge, Mass., and discussed the available information regarding the properties of steam. As a result of this conference a project of research was planned; the A.S.M.E. was requested to sponsor the program, and the raising of funds commenced under a sub-committee of its Research Committee.

As originally planned, the Harvard Engineering School was to investigate the Joule-Thomson cooling effect in superheated steam at pressures up to 600 lb. and at temperatures up to 600 deg. fahr. The Massachusetts Institute of Technology was requested to determine, under the direction of Prof. Frederick G. Keyes, the pressure-temperature-volume relation of superheated steam at high pressures and over as wide a range of superheats as possible. The United States Bureau of Standards was asked to determine the specific heat of water for a more accurate determination of the mechanical equivalent of the mean heat unit.

At the Annual Meeting session held December 5, 1922, which was presided over by Prof. A. G. Christie, of Johns Hopkins University, reports were received from those in charge of the three investigations. Geo. A. Orrok, Chairman of the Executive Committee of the Steam Table Fund, presented a brief report of the finances. He was followed by Dr. R. V. Kleinschmidt, Research Fellow of Harvard University, and investigator of the Joule-Thomson effect under the supervision of Dr. Harvey N. Davis, who described the apparatus and methods and gave values for Joule-Thomson coefficients up to the pressures at which experiments had been conducted. The work to be carried on at Massachusetts Institute of Technology under the direction of Dr. Frederick G. Keyes was outlined in a paper read by Dr. Davis in the absence of Dr. Keyes, and N. S. Osborne, of the Bureau of Standards, related plans and progress in the work to be carried on at that institution.

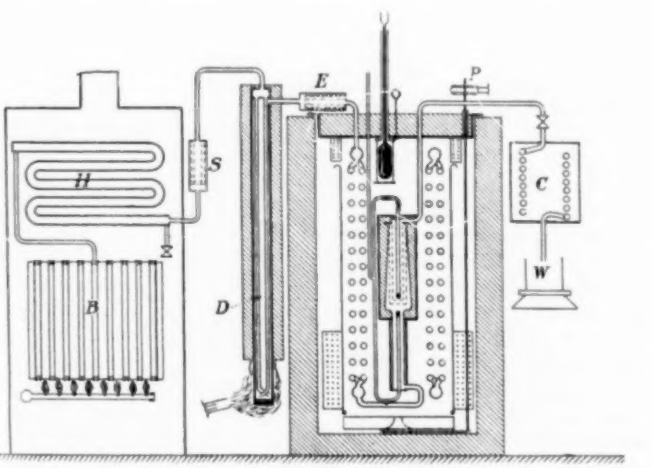

Fig. 1 General Arrangement of Apparatus

The report made by Mr. Orrok, and the remarks of Dr. Kleinschmidt, Dr. Keyes, and Mr. Osborne are given in abstract below.

Report of Executive Committee of Steam Table Fund

YOUR Committee charged with the raising of the Steam Table Fund has proceeded slowly with its work, the sum total of the subscriptions amounting to approximately $27,000. Of this $8,483 has been paid in and the second payments on the subscriptions are now due.

Your Committee has made two grants of funds and is considering three others in the near future. The first grant was made to Harvard University, to be expended under the direction of Dr. Davis on the investigation of the Joule-Thomson effect. Of this grant $5,333.50 has been expended, leaving a balance of $666.50. The second grant was made to the Massachusetts Institute of Technology, to be expended under the direction of Dr. Keyes on the investigation of the pressure-temperature-volume relations of steam. No money has been expended on this grant as yet.

Your Committee has also been considering a grant to the Bureau of Standards to cover the work which they are preparing to do, and we believe it is now time to finish the raising of the necessary money to carry all of these researches through to the end which we desire.

The Joule-Thomson Effect in Superheated Steam

By R. V. KLEINSCHMIDT,[1] CAMBRIDGE, MASS.

MEASUREMENTS of the Joule-Thomson or "throttling" coefficient, μ, in superheated steam are being made as part of the A.S.M.E. program for standardizing steam tables. Such measurements, supplemented by our present knowledge of specific heats at low pressures, furnish a convenient and accurate means of determining the total heat and the specific volume of superheated steam over any range of temperature and pressure at which the Joule-Thomson observations can be made.

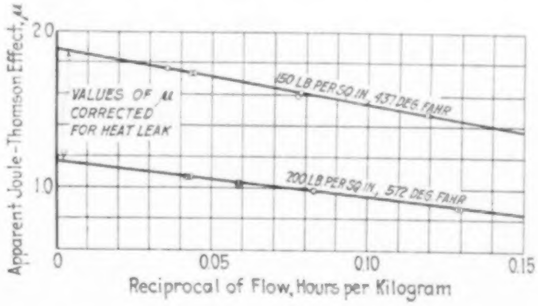

Fig. 2 Truebloop's Method of Correcting for Heat Leak

The experimental procedure consists in forcing steam—carefully dried and brought to the required temperature and pressure—through the walls of a porous tube or "plug" of alundum. The drop in pressure required to force the steam through the pores of the plug is measured on a differential mercury manometer, and the drop in temperature resulting from the throttling is measured by thermocouples read on a potentiometer.

The general arrangement of the apparatus is shown in Fig. 1. Steam is generated in a small gas-fired automobile boiler B, the pressure in which is closely regulated by an automatic control on the gas supply. It then passes through the first (gas-fired) superheater H, which acts also as a water separator. The steam then passed through a porous alundum strainer S, into a counter-current "drier" D, at the bottom of which it is heated far above the temperature at which measurements are to be made, to insure the evaporation of all drops of moisture. In passing up through the drier it is again cooled nearly to the temperature of the steam entering the drier, and it then passes through a second porous-plug strainer E, on which is wound an electric heating coil, by means of which the temperature of the steam can be very closely regulated. The steam then enters the main portion of the apparatus. This is immersed in a cylindrical tank 42 in. deep and 20 in. in diameter, heavily lagged and filled with heavy oil having the highest obtainable flash point. This oil bath is heated by electric heating coils, the current through one of them being controlled by a mercury-bulb thermostat which holds the temperature within $^1/_{100}$th of a degree or closer. The oil is circulated rapidly by a 15-in. centrifugal stirrer which sucks oil downward inside a cylindrical shield, and

[1] Research Fellow, Harvard University.

forces it up outside the shield through the heating coils. The oil bath has a tight-fitting cover from which all of the apparatus within is suspended, so that lifting the cover allows the apparatus to be removed for inspection, testing, and repair. The tight cover also makes it possible to heat the oil nearly to its flash point without great discomfort or danger from smoke and fumes.

The steam passes through a coil of eight $^1/_2$-in. seamless steel tubes, each 20 ft. long, immersed in the oil bath, and is thereby brought so close to the bath temperature that no difference can be

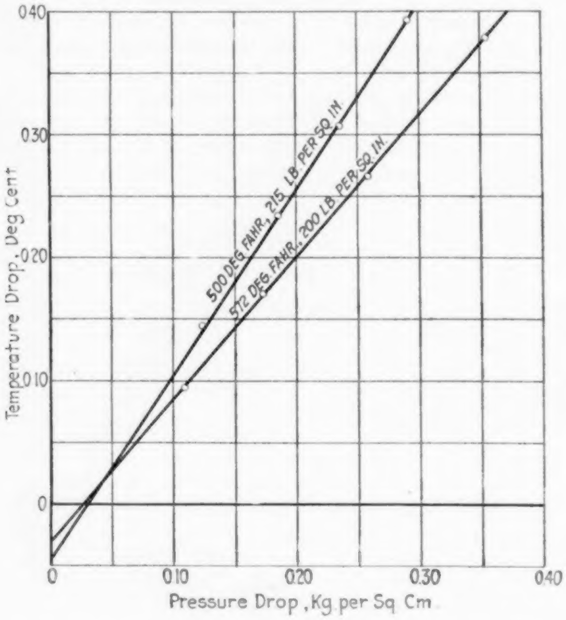

Fig. 3 Hoxton's Method of Correcting for Heat Leak

detected by a thermocouple. It then enters the "plug case" in which the measurements are taken. The plug itself is an alundum tube 1 in. in diameter, 8 in. long, with walls $^1/_8$ in. thick, closed at one end, and supported by the "plug case" at the other. The

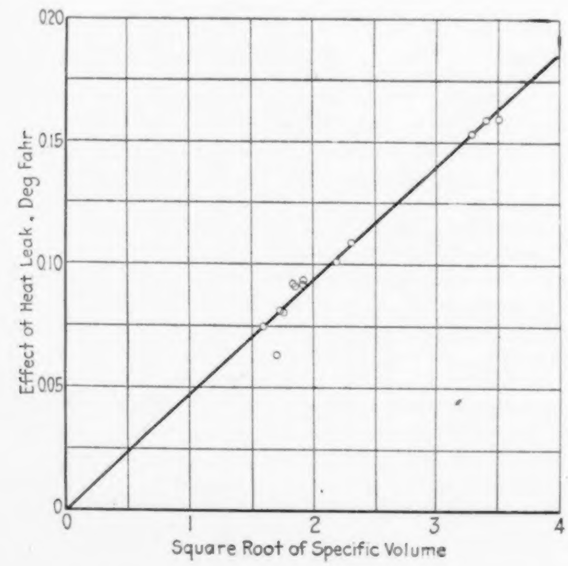

Fig. 4 Relation of Effect of Heat Leak to Specific Volume

steam, after passing the high-side pressure-gage connection and one junction of the differential thermocouple, passes around the plug and radially inward through the walls, over the other junction of thermocouple—which is placed inside the plug, near its closed end—out through the open end of the plug and out of the bath. Finally it passes through control valves into a condenser, and the condensate is weighed.

A 2-in. layer of asbestos wool provides lagging around the plug to prevent heat leak from the bath to the cooled low-pressure steam. This arrangement of the porous plug and lagging was carefully tested by Trueblood in order to get as small a heat leak as possible, and one that could be measured or allowed for, as will be shown later.

In taking measurements, readings are taken of the high-side pressure, the high-side temperature, the bath temperature, the pressure drop through the plug, the corresponding temperature drop, the rate of steam flow, and the room temperature (used in certain instrument corrections).

Observations are begun after the apparatus has been operating under steady conditions for from one to four hours, and readings

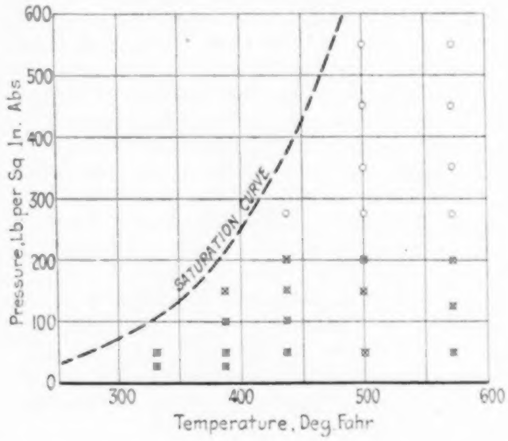

Fig. 5 Points at Which Measurements are to Be Made

of each quantity are taken as rapidly as possible over two periods of half an hour each, separated by at least half an hour. If these two sets agree closely the run is considered satisfactory and the flow is changed, keeping the high-side pressure and temperature the same as before. In this manner at least four runs are taken at different flows, with the same high-side pressure and temperature. From these runs a single value of the Joule-Thomson coefficient

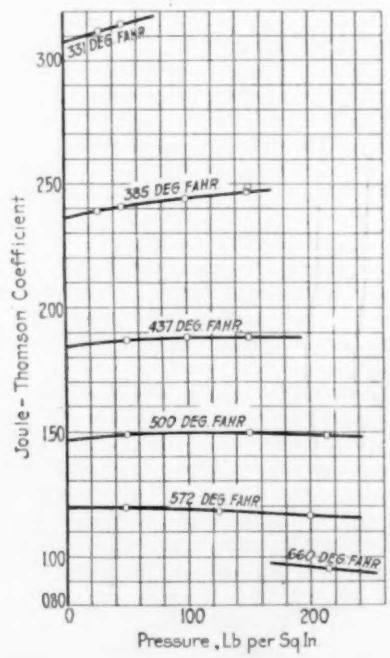

Fig. 6 Preliminary Results of Joule-Thomson Measurements

can be computed, corrected for heat leakage by one of the following methods:

1 *Trueblood's Method.* This is fully described in his paper. It consists in dividing the measured temperature drop by the measured pressure drop for each run, obtaining thereby a series of "apparent" μ's at various flows, and plotting these "apparent" μ's

against the reciprocals of the flows. These points lie on a straight line which is nearly horizontal if the flows are not too small, and the intersection of this straight line with the μ-axis (infinite flow), can be shown to be the true μ, corrected for heat leak. Fig. 2 is a sample plot of this kind.

2 *Hoxton's Method.* This method is a little easier to handle, though giving the same results as Trueblood's method. It consists in plotting the observed temperature difference against the observed pressure difference. The result, at high flows, is a straight line which, if extended, passes slightly below the origin. The slope of this line can be shown to be the true μ, corrected for heat leak, and the actual effect of heat leak is the distance below the origin at which the line cuts the temperature axis. Fig. 3 is a sample plot of this kind.

It can be proved that this intercept on the temperature axis should be nearly proportional to the square root of the specific volume of the steam passing through the plug. Fig. 4 shows that this law is closely followed by the experimental results. It is a delicate test of the consistency and accuracy of the results.

Fig. 5 shows the points at which measurements are to be made. The points indicated by crossed circles have been completed at the present writing. There are sixteen points finished and Fig. 6 shows these values plotted against pressure. On the basis of the work previously published the sign of the variation of μ with pressure is in doubt. Callendar's equation requires a rapid decrease in μ in going from zero pressure to saturation pressure. Goodenough and Heck predict an increase in μ followed by a decrease. The present work shows that the pressure coefficient is very small, whether it is slightly positive or slightly negative cannot be predicted with certainty from these results until all the corrections have been applied.

The more interesting portion of the work at high pressures remains to be done, and all the results given are subject to correction.

The Steam Investigation Program at the Research Laboratory of Physical Chemistry, M.I.T.

By F. G. KEYES,[1] CAMBRIDGE, MASS.

BEFORE proceeding with the description of the plans for the new work on the pressure-temperature relation, the liquid and vapor saturation volumes as well as the superheated region, it may be well to refer to the earlier work carried out by Mr. R. D. Mailey of this laboratory. The preliminary work of Mr. Mailey was finished about 1912, after which the entire apparatus was redesigned on the basis of the experience gained in the preliminary measurements. The redesigned apparatus included improvements in the constant temperature baths such that temperatures to over 750 deg. fahr. could be maintained constant for long periods of time to within 0.02 deg. fahr. The bath was a prime requisite, since the purpose was to carry all the measurements to over the critical temperature, about 700 deg. fahr. During the time improvements had been made in the absolute piston type of pressure gage and experience acquired in its use.

The bomb or holder for the water or steam under measurement was retained. Steel was used by Holborn and Bauman, but for measurements wherein the greatest refinement is sought the known interaction of steam with steel at temperatures of 700 to 800 deg. makes its use undesirable. Platinum was chosen and a one-piece sphere spun over a hardwood form, leaving a neck about $^3/_8$ in. in diameter. The platinum sphere with its inclosed wooden form was heated and the wood burned out. A pair of hemispheres were now turned of steel such that when they were screwed together the spherical cavity formed therefrom made a good fit for the platinum sphere. The neck of the platinum sphere was spun out laterally and the cover, platinum-faced, locked on by means of a steel union piece, using a pure gold gasket. This bomb proved to be tight up to the highest pressure (3000 lb.) and to 800 deg. fahr. Water is of course without action on platinum and it would seem to have been ideal.

In the method employed for measuring the properties of substances whose critical temperature lies low enough one may confine the substance under measurement and at the same time transmit the pressure to the devices for measuring the pressure and volume by means of mercury. In the case of steam, however, the critical temperature lies at a point where the vapor pressure of mercury is considerable, and moreover the use of the platinum bomb with a gold gasket would prevent the use of mercury. The method actually employed consisted in confining the water with itself. A very fine copper tube of 0.01 in. bore connected the bomb with a steel cylinder contained in a constant-temperature bath maintained at about room temperature. The piston used in this cylinder was of mercury, whose level could be accurately advanced or withdrawn by the intermediary of a steel piston moving through a packing gland and advanced or withdrawn by means of a screw and nut. The total mass of water under measurement is known, but one portion is maintained always at room temperature and the other at temperatures up to the limit of the range desired. To obtain the amount of water under measurement in the bomb involves taking the difference between the total quantity and that in the cylinder with which the bomb is connected. In the superheated region where the specific volume of the steam is large, the mass of water, as steam, in the bomb will be small and comes out as the difference between two large quantities, which militates against accuracy.

The foregoing are some of the larger sources of error in the work of ten years ago. During the time that has elapsed many improvements have been made in the details of the methods used in the laboratory to measure volume, pressures, and temperatures accurately. In attacking the difficult problem of the measurement of the properties of steam the Research Laboratory portion of the task is receiving the benefit of all of the accumulated experience of these years.

The plans for the renewed work on steam include the substitution of pure nickel for platinum. Pure nickel was unobtainable in homogeneous forgings twelve years ago. This metal has been found to constitute a good choice for a number of reasons. It is unattacked by steam even at 900 deg. fahr. It is uniform in its expansivity with temperature and tough enough at higher temperatures to permit of sealing with absolute tightness. It does not alloy with mercury and hence mercury can be used to measure the stretch of the bomb with increase of pressure. The true volume of the bomb can likewise be determined at a number of temperatures by means of mercury and thus the volume of the actual bomb employed will always be known in terms of weight of mercury.

Any change in the future of the densities of mercury with temperature will thus permit a recomputation of the actual bomb volumes, although there is reason for confidence in the mercury densities as at present known.

The same general scheme of confining the steam with water will be employed, using, however, two different volumetric measuring pistons, one for the saturation dome and the other for the superheat where larger specific volumes come under measurement. The connecting capillary is of nickel swaged from larger tubing to about 0.01 in. bore.

The improvement in the volume-measuring technique is such that a volume change of about one part in forty thousand may be detected. The pressure-measuring gages are of the absolute piston type floated by oil. The constant of the gages is not determined by measuring the diameter of the piston but by direct comparison with a mercury column 31 ft. in length. The equilibrium of the piston is detected by an electrical contact device which has been continually improved during the past years. The checks at different heights of mercury column with the new gages are about one part in twenty thousand. Pressures of a fluid cannot of course be measured consistently to this precision because of the difficulties of securing equilibrium, but much has been learned concerning this latter problem so that very much greater precision can be expected than in the earlier work.

The superheated field is one of particular interest from a purely scientific point of view as well as from the engineer's viewpoint. Water is regarded by the man of science as a fluid different in its properties from substances sometimes called normal such as ether, ethyl chloride, or methane. It will therefore be of profound interest to learn whether at high superheats and high pressures water vapor is indeed different in its general properties from the so-called normal substances.

[1] Dir. Research Lab. Physical Chem., M.I.T.

The Steam Research at the U. S. Bureau of Standards

By N. S. OSBORNE,[1] WASHINGTON, D. C.

THE PART of the experimental program which the Bureau of Standards undertook was a determination of the thermal-capacity of water as saturated liquid.

This problem came to us in two parts: First, the heat capacity of water, in the range from the normal freezing point to the normal boiling point, in terms of international units of energy, was wanted to establish with greater certainty the fundamental heat unit. That is to say, the mechanical equivalent of heat. This was wanted as a basis for steam-table construction. The second part, above the normal boiling point and as much higher as it was convenient to go, the thermal capacity of liquid water was desired as a further basis for steam-table construction.

This problem was analogous to one upon which the Bureau had been previously engaged, the results of which have just materialized in the form of complete tables of thermal properties of ammonia, which have just been presented at the annual meeting of the American Society of Refrigerating Engineers.

The problem of determining the thermal capacity of a saturated liquid, water, develops into a project by which, in a single apparatus, with the identical samples of the fluid, under similar conditions, with a constant degree of precision, and without dependence on other data, an entire group of thermodynamic properties, those for the saturation condition, may be determined; and it is this experimental project upon which we are at present engaged.

We have determined a general tentative design of apparatus appropriate to make these heat measurements which consists of a closed container for the fluid, made of a metal which will withstand the combined temperature and pressure without permanent deformation. The interior space is provided with an electric heater. The container in which this heater rests is also provided with an agitator, to distribute the heat so added, and promote equilibrium. The container is closed, except for outlets that provide it with valves, which may be opened or closed to permit the addition or withdrawal of portions of the fluid. If the necessary auxiliary instruments and devices are provided, we may observe the temperature of the container and its fluid content when in equilibrium, the pressure at any instant, the initial and final amount of fluid, the entire amount of heat added during any period of time, which will include that due to thermal leakage and to the energy dissipated in stirring.

The experimental processes which may occur, under the control of the operator, in connection with these observations, are three: First, by adding heat, keeping the mass of content in this calorimeter constant, its temperature can be changed; and, in addition to that, the fluid may be withdrawn from the calorimeter in two ways—either as vapor or as liquid, and, simultaneously, either by adding the necessary compensating amount of heat, the temperature may be kept approximately constant, or by adding no heat at all, the temperature may be changed.

The ones that we will use are the ones where we keep the temperature nearly constant and transfer fluid.

The experimental results of the three types of experiments can be expressed in terms of specific thermal properties of the saturated fluid, as three quantities, and the properties that come into these are the heat content of the liquid, the internal energy, plus the PV, and an expression including the latent heat, and the two specific volumes of liquid and vapor.

To the experimenter, the interesting thing about this is that all these results are obtained without the necessity of knowing either the heat capacity of our calorimeter or its volume. All that we require is that both of these things shall be definite; that is, that the heat capacity shall repeat itself at the same temperature and pressure, and the volume shall repeat itself.

In determining the design of the apparatus to accommodate this, a great many details developed, which had to do with the proper guarding against external influences on the interior part where occur the experimental processes to be observed. Other features are concerned with the control of the processes themselves, so as to make them conform to such specifications as the analysis requires. Two features illustrate the nature of the problems which arise.

In the first place, a vigorous circulation of the liquid in the calorimeter is desirable in order to attain equilibrium quickly, and so that the whole interior of the apparatus shall be bathed with the agitated liquid and its surfaces kept at a uniform temperature. Thus by controlling the temperature of the envelope, we may evaluate the outstanding thermal leakage that would otherwise exist. This circulating stream of water would be lifted to the top of the calorimeter, in order to bathe the entire interior surface. This leads to another important feature—that of locating in the top of the calorimeter, where it is continually bathed with the flowing stream, an evaporator, so that saturated steam may be manufactured and withdrawn from the calorimeter without disturbing the equilibrium within. It is proposed to furnish this circulation by a turbine pump, the duty of which will be about one three thousandth of a horsepower.

To provide means of assembling in the calorimeter parts such as these which I have mentioned, a metal shell has been developed which can be put together and made to stay tight, without resorting to any soldered joint. It is made out of a special alloy of copper and nickel—eighty per cent copper, and twenty per cent nickel. The two cup parts are threaded with a right- and left-hand thread, and one part has a groove one thirty-second of an inch in width in it; the other has a tongue which is made to nicely fit into that groove. The two are drawn together by means of a correspondingly threaded metal band, upon a ring of gold wire, one thirty-second of an inch in diameter. When we put on this double-threaded band with a powerful wrench, sufficient pressure is put on the gold washer to make it conform to the surfaces of this groove, and to make the shell tight, up to the pressure where the forces are balanced between the tension in this band, acting on the gold washer, and the forces of the hydrostatic pressure within, acting on the shell. We have found that the metal has properties to stand a pressure of 3000 pounds to the square inch. The joint held up to about 2400 pounds to the square inch, which gives us a very fair factor of safety.

The question of interaction of the water and the material in the calorimeter, can, with this device, be very well taken into account by gold plating the inside of the calorimeter and the other installation to go within.

[1] Bureau of Standards.

The Development of Machine Tools

(Continued from page 154)

turret. This improvement made possible the modern automatic lathe and similar machines. It is a tribute to the genius of Spencer that his very first automatic machine was a great success. While he is known and remembered largely in connection with the invention and production of firearms, Spencer's greatest contribution to machine production is the universal cam wheel, a device which was never patented.

These, then, are the three great advances in transfer of skill in machine tools. Maudslay's slide rest and Stone's turret are used in the construction of semi-automatic machinery more frequently than any other machine elements, while the combination of these two with Spencer's universal cam wheel is the basis of practically all automatic machines.

The importance of these inventions and improvements cannot be overestimated. The period of their development from Maudslay to Spencer was a little over one hundred years. These inventions with others of the same period embody the results of the observation, experience, and effort of the greatest group of mechanics in the history of the human race. Their achievements made possible the work of such men as Hartness, Swasey, and other great builders and laid the foundation of modern industry and transportation. Selfishness, stupidity, and lack of knowledge have as yet stood in the path of the full realization of the benefits these inventions can bestow upon all humanity. It is to be hoped that a wiser generation will be able to solve the problem of distribution in such a manner as will permit the use of these modern productive methods to fill the land with plenty.

Means for Vocational Training for the Industries[1]

Industrial Education in Extension, Correspondence, Apprentice, Shop Training, and Various Other Schools—Report of A.S.M.E. Committee on Education and Training for the Industries

BY THIS report the A.S.M.E. Committee on Education and Training for the Industries seeks to disclose the present status of industrial education and training in order to secure expert attention and advice to the end that the average efficiency of the process may be raised. The Committee believes it not unreasonable to expect that careful consideration given to this report by all concerned in promoting industrial education will result in a coördination and simplification which may be suggestive of a standard code of procedure in vocational training. This may not pass beyond the statement of governing principles associated with a prescription of the steps in the process which the end requires. At any rate, the Committee is convinced that much good will result from the discussion which this report invites.

As will be seen from the papers constituting the report, industrial education and training of a vocational nature is susceptible of classification. The considerable task of collecting and arranging the information herein presented was performed under the individual supervision of three members of the Committee as indicated by the authorship of the several papers, and to these three members and Director Moyer, the Society is under a debt of gratitude.

In general, industrial education is conducted either inside or outside the works, and sometimes uses both plans coördinately. The distinction is recognized, therefore, between apprenticeship conducted within the works and vocational, trade, and evening schools outside of the works. Correspondence work and extension schools, strictly speaking, belong to the latter of the two classifications, although these are given separate treatment in the accompanying papers on account of their special character. In each paper typical courses are presented to illustrate what may be termed "standard practice" of its kind.

It has been estimated that an exhaustive survey of the whole field in the United States to be of value in pointing a conclusion would probably cost $100,000. With no funds available and convinced that the time is not yet opportune to warrant a procedure that calls for the solicitation of funds, the Committee presents the results of its studies with the belief that the picture thus afforded will appeal to the imagination and give a fairly definite idea of conditions so far as available statistics are concerned.

EXTENSION AND CORRESPONDENCE SCHOOLS

By JAMES A. MOYER,[2] BOSTON, MASS.

[The accompanying report by James A. Moyer, director of University Extension in Massachusetts, is made by request of the Committee on Training for the Industries of The American Society of Mechanical Engineers. The first thought in relation to this is to express no opinions as to the preëminence of any school or any state but simply to give the facts that will form the basis for a larger report on Correspondence and Extension Schools in the United States. A full report in detail would demand visits to every state in the Union, and several volumes. Consequently, no attempt has been made to cover more than a fair outline of what may be found.

On account of his wide experience with extension teaching, and also on account of his connection with the Massachusetts State Department of Education where records are kept of all correspondence schools and extension departments in the United States, Mr. Moyer is very well qualified for a study of this subject. There is a slight difference between a correspondence school and a course in extension work. The latter may include the former. Correspondence instruction lacks the contact among students that promotes discussion and supplies stimulus for study, but it makes up for that in the serious purpose of every student and in what must be confessed is superior instruction. A correspondence school can afford to employ the very best talent in the country for preparing the textbooks and can lend to the work a degree of technical skill that one cannot find in the average college. The extension schools are usually connected with universities. In Massachusetts the first conception of an extension department was the education of workingmen in the industries, and to that end the technical courses were those first established. But this was in an industrial state, dependent upon technical skill for a large part of its success in manufacture. There has been a steady growth, however, toward other subjects, and Mr. Moyer has under his charge what really amounts to a university of thirty or forty thousand students.

The question might be asked, have these schools reached the height of their usefulness? Will they progress by improvement into larger fields? Their work is extremely useful, as they open the way to an education for thousands of men and women who have no money to go to college and who can profit by this kind of absentee study.

I have suggested to Mr. Moyer that he go into some details with regard to his own work as typical of many extension departments of states. If his report stimulates active thought on this whole subject by members of the Society, it will have amply served its purpose.—IRA N. HOLLIS.[1]]

CORRESPONDENCE courses in industrial subjects have been an important part of adult education for more than thirty years, and many of the courses have received wide publicity. During this thirty-year period one well-known correspondence school has enrolled nearly three million students, mostly in industrial subjects, and this same school, during the last year, sent out more than one million lesson assignments.

Besides the privately organized correspondence schools, nearly every state now has a correspondence-school system supported by taxation. These state-supported institutions are usually organized as a department of the state university, where there is one. In states like Massachusetts and New York, however, where there are no state universities, the correspondence instruction is organized in the state departments of education. Most of the state-supported institutions giving instruction by correspondence, and also some of the privately supported institutions, have given this kind of teaching the name "University Extension," which usually includes also class instruction for adults, as organized in large centers of population to take the place of correspondence instruction.

All correspondence instruction is conducted through the mails. By this method the student is sent a supply of specially prepared texts. At the end of each text a series of questions are asked which the student is requested to answer, after having carefully studied the subject-matter of the texts. These answers are sent to the correspondence school for correction. When these have been carefully corrected and graded by instructors, the percentage given is marked on the corrected paper and returned to the student so that he may see just where he has made errors.

It should be emphasized that a correspondence course comprises material organized as a basis for the instruction of a student at a long distance. It is therefore a system of instruction in which the assignment material is common to all students, but considerable variation is possible on account of the flexibility and adaptability inherent in this system of instruction. In the informational courses the differences in maturity, native ability, prerequisite preparation, etc., can all be taken care of readily and the course fitted to the need of the individual. The resultant body of papers

[1] Report of the Committee on Education and Training for the Industries, presented at the Annual Meeting, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[2] Director, University Extension, Massachusetts Department of Education. Mem. Am.Soc.M.E.

[1] President, Worcester Polytechnic Institute, Worcester, Mass. Past-President Am.Soc.M.E. Mem. A.S.M.E. Committee on Training for the Industries.

worked out coöperatively between teacher and student makes a volume peculiarly fitted to the individual needs of each person. This statement is important because in the minds of many people a correspondence course is incorrectly conceived of as a series of tests and examinations and a grading of the papers written in such tests. Work that does not rise above this procedure is not correspondence instruction. Where it follows correct procedure, the correspondence method supplies one of the most effective means by which adults may keep abreast in any informational field. Correspondence students may include those who have had little more than a common-school education, as well as those who have taken their advanced degrees from the eminent universities of the country, numbering men and women conspicuous in many professions.

Extension Classes

Extension classes are locally organized. The instructors are either members of the faculty of the university or school conducting the classes, or persons living in the vicinity in which the class is conducted, provided, of course—in the latter case—that qualified persons are available. This instruction is conducted by ordinary educational procedure. An effort is always made in extension teaching to adjust the instruction as much as practicable to the individual needs of the individual student.

Extension classes differ from residence classes in that membership in them is open to all who can give reasonable evidence of their ability to profit by such instruction; and in that these classes afford, so far as is possible in classroom work, individual attention to individual needs.

The courses offered by either of these plans range in price ordinarily from $3 to $150, depending largely on the cost of the text materials furnished, and whether or not the institution giving the course is supported by taxation.

The instructional material consists, as a rule, of lesson pamphlets prepared and published by the university or school. Each pamphlet includes from one or two to as many as twenty-five pages of explanatory or "lecture" material, one or more pages of questions which the student is to answer and submit for correction, and whatever directions the student may need as to the way in which lessons are to be prepared. Usually each course is so arranged that it may be used with equal facility either for class or for correspondence instruction.

The rapid expansion of this work has been favored from the first by the type and range of subjects in which courses are offered. For the demand for education of this kind is concerned not with particular, closely defined groups, but with the whole adult population. To be sure, in some quarters the demand is more pressing as the lack of essential education is greater; but everywhere, among men and women of every class and occupation, there is evident the desire for further opportunities to study. The bulletins describing the courses offered by the largest correspondence and university extension institutions contain upward of one hundred and fifty courses, including such section headings among the industrial courses as mathematics; drawing; steam engineering; electricity; structural engineering; textiles; natural science; commerce and management; history and government; and business economics. Within each group are comprised, as far as possible, courses ranging from the most elementary to those of college grade. The breadth of such programs, when offered by state institutions, has resulted in making every man and woman in the state a prospective student. In that case the state is offering something for everybody, and consequently the idea of continuation education has penetrated into every industry or business. The mechanic, the fireman, the engineer, the business man, the clerk—from the unlettered immigrant on the one extreme to the college graduate on the other—all are represented in the enrollments.

The problem of making these courses widely available to classes is one of reaching fairly compact, well-centralized groups, and the method of approach is accordingly direct. Agents of the university or schools consult with industrial executives, the representatives of business and social organizations, and school superintendents, and through them discover for what subjects each community has a genuine need. Instructors are then appointed, according to the nature of the courses, from college faculties or from among commercial and industrial specialists. And it is significant of the whole university-extension scheme that an instructor's formal connections and affiliations count less toward his appointment than his ability to give vital, effective instruction.

Usually study rooms and lecture halls in local school buildings, provided by the courtesy of the school departments, serve as class meeting places; and in some instances as many as half a dozen university-extension classes meet in a building on a single evening. When a class is of special interest to the employees of a certain industrial plant, it is frequently arranged to meet in the plant itself. Public-library halls and clubrooms are also used on occasion, but always with the understanding that every university-extension class, whether held in a public or a private building, is open to any resident of the state. The chief consideration in the choice of the meeting place is this: that it enables the institution to reach the people where they are.

As a tangible evidence of achievement, each student who successfully finishes a course either by class or by mail is awarded by many institutions a certificate giving the name and grade of the course, and the number of lessons completed. On certificates for all college-grade courses, the work done is usually stated also in terms of equivalent semester hours.

Advantages of Correspondence and Extension Courses

A result of correspondence courses and university extension classes less easy to estimate in formal values is the unexpected spirit of democracy to which they have given rise. Social groups which ordinarily acknowledge no common interests have learned to know of each other through the common interest in correspondence lessons; and those brought together in classes, having profited by the same instruction, have been led through class discussion to compare their views with the utmost cordiality and freedom. A non-technical course in the care and operation of gasoline automobiles, for example, has provided a common ground of interest for men and women of every occupation and walk of life. But perhaps the most effectively democratic are those classes for the training of foremen and executives in oral English, for in these particularly the students not only meet together but discuss with each other matters of general interest. There is something peculiarly personal and cordial about these classes, where each member at some time during the course addresses his fellow students on a subject of his own choosing. And the method as well as the membership of these classes is democratic, for the students both recite and criticise recitations, while the instructor, acting as a sort of moderator, takes the platform only for brief intervals, to make suggestions. From these recitations all the restraint of formal address is lacking; if other members of the class disagree with the speaker's opinions, they are at liberty to offer their own in opposition. Incidental debates are frequent; and in the interest of discussion, every shadow of social distinction vanishes.

The correspondence courses, while affording no such opportunity for student-to-student contact, are no less large in their appeal. As may be supposed, there was at first, among persons familiar only with the methods of high schools and colleges, some little tendency to regard correspondence instruction as a second-rate substitute for class work. But seldom did that tendency amount to prejudice. When class instruction in a desired industrial subject was clearly not available in a community, even the skeptical preferred to give the correspondence method a trial rather than to forego the chance of any instruction whatever. And the first experiment was usually convincing.

The student quickly came to recognize that correspondence study has its own peculiar advantages—that it is available to him at any place and at any time; that each paper he submits gets the individual and undivided attention of an instructor; that "bluffing" is out of the question—he must prepare himself on every part of the lesson; and finally, that he may set his own pace, unhurried by more brilliant students and unhampered by sluggards.

By artisans and mechanics, correspondence courses are usually accepted without question. Perhaps because the advertising of correspondence schools has long been directed chiefly at them and because many of them have already had experience in the "learn by mail" method, they have evidently had the start of their neighbors in appreciating its advantages. Most of them willingly accept

it as a substitute for class instruction, and not a few declare that they actually prefer it.

Recognizing that the common fault found with correspondence is that it lacks "personal contact," correspondence schools have set before themselves the ideal of making and maintaining between instructor and student a genuinely personal relation. That ideal is freely expressed; and every correspondence instructor is trained to respect it. With the first assignment of each course, the student is asked to submit an information sheet on which he has recorded such matters as name, address, age, occupation, and the extent of his previous schooling. This information the instructor enters on his personal records and reviews from time to time, so that he keeps in mind a rough mental sketch of the student with whom he is dealing. Some instructors who handle the papers of from one hundred to one hundred and fifty students yet maintain so intimate an acquaintance with each as to recognize his handwriting and to remember what have been his individual difficulties. This system has proved to have the double advantages of keeping the instructor constantly in touch with the student's progress so that he may more effectively prescribe and advise, and of making the student realize that his instructor knows him personally and is in a position to understand his peculiar difficulties.

But the ideal of personal helpfulness does not stop with the instructor; it is written into every course. On whatever subject, the material of the lesson pamphlet must be human, wholesome, and practical. Hypothetical problems, so far as possible, are avoided, and their places taken by problems based on fact. A certain course in textile mathematics, for example, says not, "Suppose that there are 580 looms in the ——Mill at Lawrence," but, "There are 580 looms in the —— Mill." And there are. The student gets not only a problem in mathematics, but along with it reliable facts about the textile industry.

So it is with the other courses: the instruction is concrete and tangible. The aim is to make the language of each assignment unmistakably clear; and the lesson requirements are such that the student shall be capable, under ordinary circumstances, of carrying them out. If, in spite of careful editing and supervision, faults appear after a course has been put into circulation, the instructor is on the watch for them. When his experience with students leads him to believe that a course might be improved, he makes a detailed report, in which he states what is wrong, and how, in his judgment, the fault may be corrected. If his criticism is found to be just, the course is revised.

The personal touch with students is also maintained in another way. Each month a news letter, so-called, is sent out to every person enrolled in the correspondence list. Sometimes it is merely a friendly letter of encouragement. Sometimes the letter is editorial in nature, touching, perhaps, upon the qualities of good citizenship. Sometimes it is a page of suggestions as to methods of study. Intrinsically, the news letter is a small affair, hardly to be counted in comparison with the actual work of instruction, but it seems to remind many students that in the staff of instructors, whom they may never see, there is a cordial personal interest for their success; in short, they are not dealing with a "soulless" organization.

Results of University-Extension Work in Massachusetts

The results to which these methods have led are encouraging. We have mentioned already how general has been the appeal of the courses, and how democratic has been their influence. Taking Massachusetts as a typical case, and not at all by way of expressing a superiority, but rather in order that the members of the Society may get a clearer understanding as to how this kind of instruction has grown—the advance has been almost in geometrical progression: At the end of the first year from its establishment, the Division had only a few more than 3000 students; today the total enrollment is well above 100,000, and it is significant of growth that more than a third of that number represents enrollments for the past year alone.

But numbers by themselves are less important than the geographical distribution of students and classes. It would have been comparatively simple to secure heavy enrollment by concentrating effort in a dozen or less large cities and towns, neglecting meanwhile the more remote corners of the state. This, however, has not been done. Each year active effort is directed toward filling in the gaps—toward carrying instruction into towns where university extension has not before been well represented. In consequence, there is hardly a town in the state where classes have not been held, and the post offices are few which do not handle the mail of university extension correspondence students.

Not only among students but also among many organizations and many individuals generally interested in education, the university-extension idea has spread. In certain cases these have been reached by special services such as the distribution of visual-instruction material and the publishing annually of a list of university-extension lectures for the use of women's clubs, parent-teachers' associations, and like organizations. But of even greater importance is the contact which has been established with the employers of men and women studying correspondence and extension courses. Whenever a student completes a course, unless he objects, his employer is notified and asked that, if possible, the student be given a word of commendation. The response has been admirable. Every mail brings letters from employers in which they express their appreciation for this educational work, and, frequently, report that they have personally talked with the student and have arranged for his advancement at the first opportunity. And in almost equal volume come letters in which the students themselves tell of promotion made possible through university-extension study. The student is thus encouraged to continue the work of self-improvement, which he sees has won for him favorable notice from his employer; and the employer himself is often led to ask that university-extension classes be established in his city or town for the training of his other employees.

And so, at the conclusion of its seventh year, the Division can look back with some satisfaction at the training of more than a hundred thousand students, and forward to new opportunities for services that are daily opening before it. The work of the past, by establishing contacts, has blazed a trail for the work of the future; and the time seems not far distant when every community in Massachusetts shall make its annual demand upon university extension.

Extension Work in Wisconsin

In the University of Wisconsin the University Extension Division was organized on its present basis as an extramural college with a dean and separate faculty in 1906. Some forms of extension teaching have been conducted by this Wisconsin institution since 1892. Much of the present development by correspondence study courses and extension teaching in classes has been due to the pioneer work of this university. Louis E. Reber, Dean of the University Extension Division and a member of The American Society of Mechanical Engineers, has been in responsible charge of this institution and deserves a great deal of credit for present accomplishments in this form of education, not only in Wisconsin but in all other states as well. His contributions to this subject deserve special mention. In this connection, it is interesting to note that the International Correspondence School was organized within a year of the time that extension teaching was first established in Wisconsin.

Summary of University-Extension Service in Various Institutions

Replies to a questionnaire sent to various institutions giving correspondence or "extension" class instruction have been carefully studied and grouped in Table 1. Most of the questions asked were more detailed than the headings of the columns, and therefore more explanation is necessary. The heading of column (1) means the number of years since the establishment of correspondence or "extension" class instruction in the institution. Columns (2) and (3) refer to the kind of instruction offered by the institution, that is, whether the teaching is exclusively by mail, which is called correspondence instruction, or whether it is given in classes which are not regularly organized to take the standard residence courses of the institution. These classes differ from residence classes in that the enrollment is usually permitted of adults who can be expected to profit by the instruction without, however, the educational tests of college entrance examinations, and the class is usually organized at a considerable distance from the city or town in which

TABLE 1 REPORTS FROM INSTITUTIONS GIVING CORRESPONDENCE AND EXTENSION-CLASS INSTRUCTION

Name and Address of Institution	Years Established	Kind of Instruction: Corresp.	Kind of Instruction: Class	Students 1921–22	Total No. Students Since Organization	Student Completions: Corresp.	Student Completions: Class	Cost to Student	Per Cent Students in Industrial Subjects	Positions Graduates Enter	Results of Training	Students Transfer Without Charge	Follow-up System for Encouragement
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Alexander Hamilton Institute, New York, N. Y....	13	Yes	No	48,800	167,000	0[1]	0	$136	...	Executives	Training for responsibility	Only one course	Yes
American Commerce Association, Chicago, Ill.....	8	Yes	No	....	....	?	0	$147	...	Executives	....	Yes	Yes
American School of Correspondence, Chicago, Ill..	25	Yes	Yes	18,100	104,900	5,500	10	$20–$161	60	Superintendents and executives	Interest in production and personnel	Transfer fee $3	Yes
American School of Landscape, Architecture & Gardening, Newark, N.Y.	6	Yes	No	300	800	120	0	$68–$76	35	Foremen and superintendents	....	Only one course	Yes
Carnegie College, Rogers, Ohio..................	20	Yes	No	500	8,000	600	0	$25–$100	25	....	....	Yes	..
Chicago Technical College, Chicago, Ill............	20	Yes	Yes	2,500	10,000	6,000	?	$25–$90	100	Draftsmen and superintendents	Better training for technical positions	Yes	Yes
Columbia University, New York, N. Y............	2	Yes	Yes	12,000	60,000	....	....	$10–$100	?	....	....	Yes	Yes
Hays School of Combustion, Chicago, Ill........	4	Yes	No	550	3,000	300	0	$78–$98	100	Superintendents and combustion engineers	Better training for operating positions	Only one course	Yes
Industrial Extension Institute, New York, N. Y....	3	Yes	Yes	....	5,000	?	?	$135–$160	100	Executives	Better training for executive positions	Only one course	Yes
International Correspondence Schools, Scranton, Pa....................	31	Yes	No	97,300	2,700,000	45,000	0	$65 (avg.)	100	Superintendents and executives	Training for advancement	Yes	Yes
Iowa State College, Ames, Iowa..................	9	Yes	Yes	2,400	4,000	20	2200	37½ c. a lesson[2]	100	Industrial	Better training for industrial positions	Yes	No
Knights of Columbus Schools, New Haven, Conn.	3	Yes	Yes	98,600	233,000	314	167,701	Small fees	50	Trade and commercial	Training for advancement	Yes	Yes
LaSalle Extension University, Chicago, Ill........	13	Yes	Yes	60,000	360,000	400 a mo.	500 a mo.	$36–$197	17	Executives	Better training for responsible positions	Yes	Yes
Mass. Department of Education, Boston, Mass....	6	Yes	Yes	36,800	114,700	10,900	36,500	$1–$10	30	Foremen, superintendents and engineers	Training for responsibility	Yes	Yes
McLain's System, Milwaukee, Wis..............	14	Yes	No	238	4,400	3,300	0	$135–$150	100	Foremen, superintendents and inspectors	Better training	Yes	Yes
Nova Scotia Technical College, Canada...........	1	Yes	No	189	189	48	0	$2–$14	50	Varied	....	Yes	Yes
Pennsylvania State College, State College, Pa.......	10	Yes	Yes	13,300	104,000	?	50,000	$3–$10	60	Superintendents and engineers	Training for foremen	Yes	Yes
United Y. M. C. A. Schools, New York, N. Y........	12	Yes	No	9,000	33,000	?	0	$60 (avg.)	40	....	....	Yes	Yes
University of California, Berkeley, Cal...........	9	Yes	Yes	24,100	62,800	?	?	$6–$12	20	....	....	Yes	Yes
University of Chicago, Chicago, Ill...............	31	Yes	No	6,500	30,000	15,000	0	$19–$50	20	....	Better training	No	Yes
University of Colorado, Boulder, Col...........	10	Yes	Yes	2,000	6,600	60	2,200	$3	50	Foremen, superintendents and engineers	Better training	Yes	Yes
University of Kansas, Lawrence, Kan.............	12	Yes	Yes	2,700	14,300	4,000	2,600	$4–$20	10	Foremen and superintendents	Better education	Yes	Yes
University of Minnesota, Minneapolis, Minn.....	9	Yes	Yes	5,800	30,300	1,300	22,400	$5–$17	20	Draftsmen, surveyors and superintendents	Better engineering training	No	Yes
University of Missouri, Columbia, Mo............	12	Yes	Yes	800	6,100	3,100	300	$4–$10	...	....	....	Yes	Yes
University of North Carolina, Chapel Hill, N. C..	2	Yes	Yes	400	475	....	....	$6.50–$12	20	....	....	Yes	Yes
University of Tennessee, Knoxville, Tenn.	Beginning this year									Beginning this year			
University of Wisconsin, Madison, Wis...........	16	Yes	Yes	29,400	79,000	40%	50%	.62½ c. per lesson[2]	25	Superintendents and engineers	Increased efficiency	Yes	Yes
Washington State College, Pullman, Wash..........	3	Yes	Yes	300	1,000	200	300	$3–$10	20	Widely varied	....	Yes	Yes
Washington University, St. Louis, Mo.............	7	No	Yes	1,800	4,000	0	2,000	$10–$30	50	Foremen and superintendents	....	...	No
Wilson Engineering Corporation, Hanover, Mass..	10	Yes	No	200	3,200	?	?	$70–$220	100	Steel and concrete engineering	Better training	Yes	No

[1] No examinations or certificates.
[2] Necessary textbooks extra.

the parent institution is located. In column (4) are tabulated the number of students who received instruction in the school year 1921–1922; and, on the other hand, in column (5) are recorded the total number of students who have received instruction in the institution since its organization or establishment. Columns (4) and (5) include, therefore, the total enrollments of both correspondence and class students for the times specified. "Student completions" as referred to in columns (6) and (7) means the number of enrolled students who have satisfactorily completed their courses either by correspondence or in classes from the time of the organization of this form of instruction to the date of these reports (about July, 1922). There is considerable variation of practice in the institutions included in the tabulation as to the kind of record for "completions." Some institutions give certificates and others give only "credits" on the records of the institution. Some courses are also much longer than others; even the same institutions will offer some short courses and some long courses so that a high record for completions obviously means more when referring to long, rather than short, courses of study. Column (8) does not mean the cost to the institution for instruction, but is the amount charged students for enrollment, and although there may be exceptions, includes as a rule the text materials that the student actually requires. In some cases where the necessary text material is obviously extra, this has been noted by reference to a footnote. Column (9) refers to the percentage of the total number of persons enrolled in the institution for both correspondence and "extension" class instruction who are taking industrial (engineering or industrial trade) subjects. Column (10) is under the heading "Positions Graduates Enter" and the replies were not satisfactory for tabulation because of the great variety. The reply of one institution was, "Practically all are in industries;" and three others replied, "Various." The tabulation of this column, therefore, gives very little useful information. Column (11), headed "Results of Training," is an abbreviated statement for the following question: "What effect have these schools (meaning those giving correspondence and extension-class instruction) upon the education of foremen?" Some replies were received which could not be stated briefly enough for tabulation. For example, the University Extension Division of

the University of Wisconsin reports as follows: "It has a wholesome and stimulating effect. Where the instruction has been specifically organized as foreman training instruction, the result has been to increase their efficiency as a direct applied result. Where the courses have been general or avocational the instruction has added to the resources of the student in ways that are equally valuable as compared with its having only the vocational bearing." The correspondence school which has reported the largest enrollment has sent an explanation of this question in the following interesting paragraph: "As explained in our preceding answers, most of our students are already engaged in occupations of various sorts at the time they enroll for our courses. For this reason, we feel safe in saying that practically every journeyman in any trade enrolls for a course with a view to bettering his position. A machinist, for example, usually enrolls for a course in mechanical engineering or a closely allied course with a view to becoming a shop foreman. Furthermore, we have a course for foremen. This course deals mainly with the employing and handling of labor, safety fundamentals, and ten lessons which are entitled 'Training the Executive.' A man enrolling for this course is supposed to have mastered the technical end of his trade, or else he would not occupy the position of foreman. To sum up the answer, we feel that our school plays a very important part in the education of foremen." Column (13) refers to methods of instruction and is more interesting to educators than to persons engaged in industry.

SCHOOLS FOR APPRENTICES AND SHOP TRAINING

By R. L. Sackett,[1] State College, Pa.

The object of apprentice training is to train a sufficient supply of young men to meet the need for skilled employees, including foremen and superintendents. It is believed that thorough training stabilizes employment, reduces turnover, gives a better understanding of elementary economics as applied to industry, and tends to "create a greater interest in and loyalty to the concern."

A number of developments have occurred within the past year indicating an appreciation of the need for apprentice training. The Industrial Association of San Francisco, for instance, an organization of employers, because of the difficulty in obtaining sufficient skilled labor and the high wages demanded, has been led to establish schools for plasterers and plumbers. They plan to open other schools for bricklayers, steam fitters, carpenters, electricians, and others. Out of 75 who responded to the first call for plasterer apprentices, 25 passed the preliminary tests. During the training period of 12 weeks, the trainees are paid $2.50 per day of eight hours and are taught by skilled workmen. At the close of the course they are put on regular work at good pay, and at the end of a year are to be rated as journeymen.

In training plumbers the plan is somewhat different. The apprentice has two weeks of schooling, then goes as a helper for four weeks on real jobs and then returns to the school.

The report says that the association believes that it can train men to be master craftsmen in 12 to 18 months, whereas three to four years have been demanded in the past.

The New York Building Congress Apprentice System

The most extensive program of apprentice training that has been recently developed is one prepared by the New York Building Congress, which is an organization composed of representatives of the architects, builders, and trade unions. A committee on apprenticeship was organized in January, 1922, "in response to a demand on the part of the building industry to develop men better trained in their craft and in citizenship than present-day trade conditions provide or permit."

The Committee states the purpose of the movement as follows:

> The Committee was established for the purpose of fostering the development of the apprenticeship in the building trades, not by dictation, but by acting in an advisory capacity with similar committees from the various interests represented in the Congress.
>
> The Committee proposes to coöperate with all other committees, organizations, and movements of trade, labor or educational interest, by bringing their activities together and overcoming the difference or inertia that has existed and which has done so much to handicap, if not to frustrate, the best interests of training in the building trades.

The policy and the general plan have been adopted by both the New York Building Trades Employers Association and by the Building Trades Labor Council, representing the unions. The joint plan is in operation and was first applied to woodworking apprentices after the carpenters unions had approved the idea. The general plan of the apprenticeship is for the apprentice to learn his trade on the job and receive his instruction in related technical studies during part-time attendance at school. The intention is to utilize the public continuation and evening schools so far as practicable but where such coöperation cannot be obtained the Congress will open its own schools.

There is sufficient evidence of an adequate supply of apprentices ready for training, and plans are being made for the organization of training for plasterers, bricklayers and other trades as soon as practicable.

This movement by the New York Building Congress has the support of financiers, contractors, and union labor and it has aroused widespread interest in the problem of supplying an adequate number of skilled mechanics and artisans. There is an encouraging sign in the announcement by the Committee that—

> The employers see the need of a constructive and sound system for recruiting skilled help and the unions realize that the trades should be dignified with a true educational merit and background.
>
> It is proposed to proceed carefully and to develop along other occupational divisions in the Building Trades until the entire field is covered, our purpose being to expand gradually so as to build up a system of good sound training that will not only meet the needs of the business but also provide an educational opportunity for our young men.

Building-trades magazines and a wide variety of associations in other cities have expressed their interest in and have endorsed the plan. It is the most conspicuous development of the year in its line. It marks the confession by employer and unions of a recognized need; it is an outstanding evidence of possible and desirable coöperation and it is an acknowledgment that there are educational methods which will expedite the preparation of skilled men.

Railroad Apprenticeships

The railroads have been from the first strong advocates of an apprentice system. They have two classes, namely, those having a common-school education, and those who have been graduated from a technical college.

Those with a common-school education are given class work in mathematics, mechanical drawing, physics, and elementary mechanics along with their shop work.

Those who have a technical education are put on more advanced repair, maintenance, design and construction—principally in the motive-power departments.

The pay of apprentices on railroads has been increased until it represents a fair wage.

Industrial Apprenticeship

In 1918 the Westinghouse Electric and Manufacturing Company, of Pittsburgh, added an apprentice drafting course to its educational work.[1] The course consists of two years of eight terms of three months each. The class periods are two hours in length and classes meet three periods per week. The following information was received, which will make clear the object and methods employed by a company which has conducted shop and apprentice training for many years.

The entrance requirements specify high-school graduates or the equivalent.

The apprentices spend the first few weeks in the Educational Department where they are given a very intensive course in tracing. They are then transferred to one of the Drafting Divisions where they remain for the first year, after which they are transferred to the shop and scheduled through the Pattern, Foundry, Forging, Machining, and Assembling Departments for the next six months. This enables them to acquire the actual shop experience so essential to designing. After completing their shop experience they are

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[1] The details of this curriculum may be obtained on request from the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

brought back to the Drafting Division for the remainder of the course.

The terms in general cover Objects of Drawing, Drawing System, Hand and Machine Tools, Patternmaking and Molding, Shop Practice, Materials and their Application in Manufacture, Development and Sections, and Clearances and Allowances. The mathematics in the course range from the fundamentals of arithmetic to the strength of materials in concrete problems. It might be well to mention the fact that the aim is first to make men, and that the various processes are accordingly used to instruct the boys, rather than to teach the processes.

When the course is completed, the graduates are transferred to the Engineering Department as regular employees.

Fifty-two apprentices have been enrolled in the course at this writing. Twenty of this number are still with the company, making the total turnover from the very beginning of the course, four years ago, only 61.5 per cent. Eleven have been graduated and three of their number have entered college. The remaining eight are still in the Drafting Office. Ten left the course on account of remuneration and three of them have returned. Of the twenty remaining with the company, six have been there over three years; five others have been there over two years; and the remaining nine have been there over one year. Only one of the total number was discharged.

This company also has apprentice courses for machinists, toolmakers, foundrymen, patternmakers, electricians, and junior engineers.

The applicant for trades training is interviewed by at least two different individuals and is given a simple test in mathematics. Those accepted are placed on probation for a period of three months. Their record is checked monthly by a trades apprentice committee and at the end of three months a definite decision is made as to whether an agreement shall be entered into between the young man and the company. If the young man and the company desire, a contract is entered into at this time outlining the obligations and duties of both parties. The apprentice is then placed in a special department in the factory where he receives preliminary instruction by specially qualified instructors. Supplementing the shop work each apprentice reports to the trades apprentice school four hours each week, two hours of instruction being devoted to blueprint reading and mechanical drawing, includirg tool design; and the remaining two hours divided between shop problems, economics, science, and manufacturing operations.

The National Metal Trades Association

This association also has an apprentice-training system which has been in operation for several years at different plants. It maintains an educational director who devotes his time to the study of apprentice training and shop instruction.

The Committee on Industrial Education of this Association says:

> Investigation in the metal-trades industry has shown that while in normal times there is a fair supply of semi-skilled specialists, there is always a dearth of skilled, all-around craftsmen. These highly skilled men are not only indispensable in the shop, but it is to this group that industry must look for its future foremen, superintendents and managers, and for practical designers and engineers.
>
> So pressing has this need become, that serious thought must be given to methods of adequate training of young men for this purpose if we would stimulate and not stifle the fullest development of American industry.
>
> Mindful of its urgency and realizing the consequences which must follow continued indifference toward this important question the National Metal Trades Association, after an exhaustive survey of the situation, has prepared a plan of apprentice training which, with slight modifications, will adapt itself to a shop of any size.

The association has adopted a standard form of indenture, setting forth in full and clearly all the details of compensation, service and training. Provision is made for a probationary period of three to six months, and by examination an apprentice who has had additional schooling may reduce the period of apprenticeship. Wages paid vary with the progress of the trainee, ranging from $33^1/_2$ per cent to 85 per cent of a journeyman's wages.

An interesting provision is made by which a highly specialized plant may send its apprentices to another plant for part of their training. This is a new type of "coöperative training;" in this manner they obtain the best instruction available in a group of industries.

Careful records are kept of each apprentice and his progress in learning each process. Each instructor grades each man on such qualities as speed, accuracy, etc., as well as on his skill on the particular process. The final record card shows the details of the four-year course, the time used, grade and instructors' estimate of personal qualities. The entire scheme is carefully planned and recognizes the rights and duties of the apprentice and of the company.

To a questionnaire sent out by the National Metal Trades Association, 572 replies were received. Of these 146 stated that some method of apprenticeship was being used, 72 train their operators, and 68 conduct foreman training classes. Of those training apprentices, 81 use the method of casual training by foremen, workmen, or by observation and practice, and 49 have definitely planned systems of instruction either in the production department or in an independently organized training division.

Shop Training

During the world war, various quick methods were adopted for training men for jobs with which they were more or less unfamiliar. Most of the methods had been used in industry for some years, but neither so extensively nor so intensively as in war work. Out of the experience of peace and war have come certain well-defined methods of training men for new jobs. These may be classed as:

1 Vestibule schools, where the training is in an independent organization and not in the production department.

2 The shop school conducted within the production department. This instruction may be by classes, by groups, or by special instruction for works clerks, routing clerks, and others of whom there are only a few in any plant even though it be large.

Vestibule Schools. There is no uniformity in the use of this term. It will be used here to define that type of training conducted in a separate shop where the trainees are segregated from those on production. Here it is proposed to give the "one best way" of doing a certain operation under good conditions. Learners are not distracted by the comments of other workmen. They do not learn the wrong way. They do not take the time of a foreman from production. They do not waste so much material.

On the other hand, a separate training department is not justified in the average small plant, but only where the demand for new, trained men is fairly constant and considerable. The separate school depends on the production department to absorb its output and if there is not close coöperation between the two, the separate school will be unsatisfactory.

The instruction often consists of one or two periods per day of classroom work and the remainder is spent on the process or operation to be learned.

The instructors should be chosen from the skilled men in the production department who have the ability to transmit what they know and tact in doing it. The production department will naturally object to losing one or more of its most valuable men for this purpose.

Shop Schools when conducted in the production department have the advantage of a certain elasticity. Instructors not required at the time can be put back on production. The majority of plants employ this method, and the foreman is most frequently the teacher. The modern demands on the foreman are much more severe and exacting than they used to be. To ask him to be a teacher also is a questionable expedient except where the number of trainees at one time is small. Where the plant expects foremen to be teachers, it seems reasonable to instruct them in methods of teaching.

The instruction is usually for the sole purpose of increasing the immediate productivity of new employees, saving waste of materials, and reducing wear and tear on machines. The training of apprentices is much broader and includes more of the industrial and economic background of production. The Federal Board for Vocational Education, in Bulletin No. 48, urges the importance of teaching in shop schools, the character of and sources of the materials used, the general processes of manufacture, the purpose and principles of planning and routing, the definition of terms frequently used, reading blueprints, job tickets, safety, welfare, hygiene, and the elimination of waste.

Wages During Training Period

In a plant where piece rates prevail a beginner will often become

discouraged and quit before he has learned the process and become sufficiently skilled to make a reasonable wage. It is usual to provide a special day rate during the period of training so that the trainee will be assured of a certain minimum income until he has the skill necessary to earn a higher wage on a piece-rate basis of payment.

Another method is to give the trainee a bonus, during the learning period, on the regular piece rate, depending on the production reached. If he does not accomplish the minimum production set he has the fixed day rate, and if he reaches or exceeds the minimum production he receives a bonus on the piece rate.

Where contracts are let to a group to construct or erect parts or the whole of a complicated machine, the cost of instructing a new man is sometimes borne by the group as a part of the total cost or contract price.

Where a group of workmen in a particular shop are held responsible for the instruction of new men, a leader is appointed who sees to the supply of tools, materials and the set-up of machines. The earnings of the leader may be charged to overhead, but enter into the cost of the job in that shop. In this manner the earnings of the group and of the individual are affected only by the time given by each man to instruction and not by the loss due to the reduced production of the leader.

A record card is kept of each learner, giving the time required to master each machine or process, the production output, and comments of the instructor or foreman on the progress of the learner. The time card also gives valuable information as to the capacity of different men to teach—or their indifference.

Difficulties in Shop Training

The old method of having the foreman "break in" the new men presumed some knowledge of the job by the employee and was in vogue when the foreman's job was much simpler than now. Because of this custom and the desire of some foremen to continue this duty, it is difficult to convince the management of the desirability of having trained teachers, i.e., men of skill who have been instructed how to teach. Too frequently a man is chosen to teach just because he knows the subject. Very often one who is not an expert becomes a better teacher because he has the gift or has been trained in the process of teaching.

Experience has demonstrated that assigning to the teaching an assistant foreman who has been trained to teach, or a selected workman who has the qualities of a teacher, is economy. In other words, the organization of teaching is important, and is increasingly important as the number of trainees increases.

Unfortunately there are very few books on teaching which are written for and adapted to this particular condition. However, a stimulus to the training of industrial teachers has been given by the Smith-Hughes Act—a federal law which provides funds with which to train industrial teachers for service in shops and in continuation and trade schools. Each state has an organization for this purpose operating under the joint supervision of the state department of education or public instruction and the Federal Board for Vocational Education.

The expense of maintaining trained instructors who are non-productive is frequently an objection in the eyes of the management. It is difficult to show by figures the reduced time and materials used in learning, the saving in wear and tear on machines, the saving in the foremen's time, the reduced turnover during the training period, the lessened interference with production, and the greater satisfaction to piece workers when they are not asked to break in new men.

Good instruction insists on doing the thing in the right way, and then learning to do it as fast as possible by correct methods. Production insists on doing the work as fast as possible, though the methods pursued may not be the best and ultimately may not lead to the greatest possible production commensurate with the effort made. There is a natural conflict between good instruction and the purposes of the production department which is not given due weight. It has been found that those who have received a thorough apprentice training often make good teachers because they have been thoroughly trained and have learned in the logical order, i.e., they have been given the simplest jobs first, then the more complex, while the desire to obtain early production may lead to an illogical order in the instruction of a new man and a waste of time.

Selection of Men

Another difficulty arises from the fact that in many plants there is little attempt to select men who are adapted to the job. An increasing number, especially of the larger plants, select both apprentices and skilled workmen (or those who are to be trained in some process requiring skill) with care. Educational tests of a simple character are given applicants for apprenticeships and systematic questions tending to establish fitness or unfitness are being applied to mature applicants. Trade and psychological tests were applied during the war and a valuable body of information and experience was gathered. There is much that is sound, and when turnover costs from one hundred dollars per man to twice that, it seems the part of wisdom and economy to apply discriminatory tests to all applicants, keep a simple record, and test the efficacy of such tests by experience. There are numerous sources of information on this subject such as the bulletin of the National Personnel Association, The Instructor, the Man and the Job, by Charles R. Allen,[1] and various journals on applied psychology, management, etc.

In conclusion, it is safe to say that whether the shop training should be done in a separate department or on the production floor depends on the size of the plant, normal turnover, complexity of the job to be learned, and other factors. In any case more attention should be given to organizing the instruction, selecting those to be trained with more discrimination, selecting instructors because of their skill as workers and as teachers, and so arranging the instruction as to give the new employee the best information available about his job, the methods, materials, and machines used. Some day we shall realize the importance of giving him a reflection of company ideals, methods of recognizing ability, faithful service, and loyalty. Perhaps industry will see the wisdom, even economy, of teaching its younger men the fundamental principles upon which a sound future industrial policy must rest. Up to the present time industry has had very few ideals, with marked individual exceptions, and such ideals as it may have had have been carefully locked in the safe rather than spread among the employees.

Industrial management in the United States, speaking broadly, has never used educational methods for its own salvation and for the upbuilding of industry. However, some have appreciated the value of teaching and have found such methods distinctly effective.

INDUSTRIAL EDUCATION AS REPRESENTED IN SCHOOLS

By C. R. Richards,[2] New York, N. Y.

THIRTY years ago, the demand was often voiced on the part of employers for trade schools to train mechanics competently in place of the disappearing apprenticeship system. During these thirty years a number of attempts to meet this demand in schools both under private and public control have been made but the results and experience gained have not demonstrated that this function is one that can be served effectively in a large way by a school.

Outside of a number of schools run on a business basis for profit there are at present in the United States some fifteen or more schools that, strictly speaking, may be called trade schools, that is, schools admitting applicants sixteen years of age or over and aiming to train manual workers for a trade. The first of these, the New York Trade School, was founded by Richard T. Auchmuty in 1881. The development of schools aiming to take the place of apprenticeship in whole or in part after this date was very gradual—the Williamson Free School of Mechanical Trades was founded in 1889 and the Baron de Hirsch Trade School in 1891.

In 1907 the trade school entered upon the stage of public administration. In that year the Milwaukee School of Trades previously established was taken over by the city under the terms of the Industrial Education law passed by the Wisconsin legislature. Since that date public trade schools have been opened in Philadelphia, Pa., Portland, Ore., Bridgeport, New Britain and other places in

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[2] Director, Cooper Union. Mem. Am.Soc.M.E.

Connecticut, Worcester, Mass., Yonkers, N. Y., Indianapolis, Ind., and Scranton, Pa., together with several institutions on private foundations such as the David Ranken, Jr., School of Mechanical Trades at St. Louis, the Arthur Hill School of Trades at Saginaw, Mich., and certain departments of the Dunwoody Institute, Minn.

Certain of these schools—the New York Trade School and the Baron de Hirsch—represent the short-course type; the others offer courses of two or three years in which practical trade training is supplemented by instruction in drawing and technical practice and in some cases by science and mathematics.

One reason why schools of this type have not further increased in number is because of the severe economic difficulties under which they labor. First of these difficulties is the problem of support presented to the student worker during the period of instruction. Trade school training of the type under discussion is in common practice restricted to the period above sixteen years of age, and as the great bulk of the youth who will form the mechanical and industrial workers of the country must of necessity enter upon remunerative work at sixteen or shortly after, the sacrifices necessary to permit attendance at a trade school can be expected only from a comparative few. The second aspect of the economic problem in relation to such schools is found in the large expense of administration, instruction, materials, and physical maintenance in proportion to the number of students that can be instructed. To be successful the trade school must demonstrate not only that it can give a better training than that obtainable under practical commercial conditions but that it can give training so much better as to compensate for the loss of wages during the learning period. At the best it is only in a few high-grade trades, the full command of which involves extensive subject matter and breadth of experience, that trade-school training can claim sufficient advantages over training under commercial conditions to repay its expense. It is, consequently, only in cities representing exceptional concentration of such industries that trade schools, at least of the long-course type, can expect support, and it is not yet entirely clear even in these cases whether the results obtained are proportionate to their expense.

It is in other fields that the large place of the school as a factor in industrial training has become evident—in the fields of preparatory and supplementary education. Here the schools have demonstrated their great value.

To properly estimate the place of the school in this whole connection it is essential not only that some knowledge be had as to what is being done in schools at the present time, but that an understanding be developed as to what forms of instruction can be most effectively consummated outside of the industries—that is, in schools; and what phases can be developed effectively only inside the industries. Both types of training are essential in a comprehensive system of industrial education—one is complementary to the other—and both need to be encouraged with intelligent discrimination in order that they may be developed as parts of an effective whole.

Evening Schools

The largest development of supplementary instruction has been in the evening school. This type is the earliest development of industrial education in our country and today reaches the largest numbers. Cooper Union and Mechanics Institute of New York; Franklin Institute and Spring Garden Institute of Philadelphia; The Ohio Mechanics Institute of Cincinnati; and the Virginia Mechanics Institute of Richmond all opened their classes about the middle of the nineteenth century. These schools were all due to private initiative and it was only slowly that schools under public administration entered this field.

The early work of the evening industrial and technical classes consisted of various lines of drawing, to which were gradually added courses in science, mathematics and technical subjects. Beginning about 1890 certain of these institutions established practical shop courses in a few of the high-grade mechanical trades intended to broaden the experience obtained by the student during the day.

The concern of public evening schools was formerly almost entirely with general studies and it is only of late years that differentiated and specialized courses related to industrial practice have been introduced in the schools of the more important cities. The expansion of such work, however, is now going on rapidly. In New York State in the year 1920–21 there were enrolled 22,984 men and 4,222 women in evening industrial extension classes under public administration, admission to which required actual employment in a related trade. The law in this connection states:

> Evening vocational schools (may be established in cities) in which instruction shall be given in the trades and in industrial . . . . subjects which shall be open to pupils over sixteen years of age, who are regularly and lawfully employed during the day and which shall provide instruction in subjects related to the practical work carried on in such employment.

A list of the evening industrial courses for men given during the year 1921–22 in New York State is as follows:

- Auto mechanics
  - Auto-block testing
  - Chassis repairing
  - Engine repairing
  - Gas-engine theory
  - Lighting and starting
  - Storage batteries
  - Vulcanizing and tire repairing
- Architectural drafting
- Blacksmithing
- Book illustrating
- Clay modeling
- Commercial photography
- Cooking and catering
- Dental trade (mechanical dentistry)
- Electricity
  - Alternating-current theory
  - Direct-current theory
  - Electric installation (house wiring)
  - Plan reading and estimating for electricians
  - Principles of artificial lighting
  - Radio
  - Railway signal work
  - Telegraphy
  - Telephony
  - Underwriter rules and regulations
- Foreman training
- Hydraulics
- Industrial chemistry
- Interior decorating
- Jewelry design
- Life drawing
- Machine shop
  - Advanced machine-shop practice
  - Elementary machine-shop practice
  - Blueprint reading for machinists
  - Mechanical drawing for machinists
  - Free-hand sketching for machinists
  - Shop mathematics for machinists
  - Theory of materials and processes
  - Tool designing
  - Tool making
- Mechanical drafting
  - Advanced mechanical drafting
  - Elementary mechanical drafting
- Mill wrighting
- Motion-picture operating
- Mural designing
- Player-piano mechanics
- Plumbing and heating
  - Leadwork
  - Plan reading and estimating
  - Principles of heating and ventilation
  - Hot-air system
  - Hot-water system
  - Steam heating
- Poster designing
- Printing
  - Advance hand composition
  - Cost estimating
- Elementary hand composition
  - Job and cylinder presswork
  - Kelly press operating
  - Monotype operating
  - Offset presswork
  - Photo lithographing
  - Proof reading
  - Typographical design
- Sheet metal work
  - Plan reading and estimating
  - Sheet-metal drafting
- Shop mathematics
- Ship drafting
- Ship fitting
- Shoe finishing
  - Cobbling
- Sign painting
- Steam engineering
- Textiles
  - Garment-machine operating
  - Knitted fabrics
  - Lace designing
  - Loom repairing
  - Men's tailoring
  - Ribbon manufacturing
  - Textile chemistry
  - Textile design
  - Women's tailoring
- Woodworking
  - Advanced cabinet making
    - Elementary cabinet making
    - Drawing for cabinet makers
    - Blueprint reading for carpenters
  - Framing
    - Millwork
    - Inside finishing
    - Plan reading and estimating
    - Stair building
    - Use of steel square
    - Patternmaking
- Terra-cotta work
- Upholstering
- Welding
  - Electric
  - Oxyacetylene

The attendance in these trade extension courses in New York City during the year 1920–1921 was 13,538 men and 3,969 women.

Part-Time Classes

Part-time classes are a development of comparatively recent years. Laws making it permissive for municipalities to develop part-time classes in place of evening classes for employed boys and girls who had not finished the elementary school began to appear as early as thirty years ago. The first law making attendance compulsory in such classes was that of the state of Wisconsin in 1911.

This action was followed by other states until the number that have enacted such laws now reaches twenty-one. As long as these compulsory school laws referred only to boys and girls up to the age of 16 years they had limited significance from the standpoint of industrial education as the instruction given was necessarily largely of a general nature. In 1917 Wisconsin passed a law making attendance in a part-time school compulsory for all employed boys and girls up to 18 years of age. Since that time such laws have been passed in 10 states with the result that opportunities for imparting valuable instruction in matters related to the needs of the vocation in which the boy or girl is employed have developed. The opportunities for rounding out and broadening the education of the young workers in the industries thus presented are very important although the extent to which such instruction can function on the industrial side is largely dependent upon the size of the community in which such classes are maintained or upon a degree of industrial concentration in the community which will allow classes from single or related industries to be segregated so that specialized class instruction can be given.

The large opportunities for related vocational instruction in this field lie in connection with the high-grade trades involving considerable content of trade or technical knowledge depending on an understanding of elementary mathematics and science. In the case of low-grade factory industries where neither processes or materials present need for technical knowledge the school instruction must necessarily assume other directions.

The results of such instruction, however, whether dealing with pupils from skilled trades or factory industries, have been found of much assistance to foremen and superintendents in determining promotional opportunities inside the plant.

The numbers in part-time classes in New York state in the year 1921–1922 were 26,678 boys and 21,760 girls. The New York state law requires that part-time schools shall be established in cities and school districts having a population of five thousand or more inhabitants and that each minor under age of 18 years who is not in regular attendance upon some public, private or parochial school or who is regularly employed in some occupation, unless he has completed a four-year secondary course of instruction, shall attend a part-time school. Such attendance shall be for not less than four hours a week and not more than eight hours a week. These hours should be between the hours of 8 o'clock forenoon and 5 o'clock afternoon. This law was put in operation September, 1920, and municipalities are given until September, 1925, to put the law into full operation.

At the present time practically all cities outside of New York City require the attendance at such schools of all employed minors 14, 15, and 16 years of age. New York City requires the attendance of those 14, 15, and 16 years of age when they are not elementary school graduates. Schools or classes are now in operation in 103 communities in the state.

Part-time instruction is apparently destined to increase throughout our country until it reaches all employed youth up to 18 years of age. Under these conditions the study of just what elements of instruction can be given best in these classes is a matter of much importance and one requiring thoughtful consideration. The subject is receiving considerable attention and the elements of the problem have been very well analyzed in a bulletin recently put forth by the Federal Board for Vocational Education called "Part-Time Schools."

Vocational, Industrial, or Unit-Trade Schools

Preparatory industrial training or pre-employment trade training is represented in its most important phase by schools under public control called, variously, vocational schools, industrial schools, or unit-trade schools. These schools have arisen largely from the discovery of the fact first brought out by the report of the Massachusetts Committee on Industrial and Technical Education in 1906 that in the case of the large number of boys entering employment at 14 years of age, the two years following are largely wasted as far as progress toward a skilled trade is concerned.

The first school of this type to be established was at Rochester, N. Y., in 1908. Since then a considerable number of schools providing practical work in one or more of the large trade groups, together with related instruction in drawing, elementary science, history, English, shop calculations, accounting, and business forms have been organized in several eastern states. Such schools do not aim to impart a trade training but to develop some amount of industrial intelligence and knowledge of shop methods and materials in the boy or girl 14 or 15 years of age that they may be better prepared at 16 to enter upon industrial employment.

The causes that have brought the preparatory trade school into being in the United States are not alone the economic advantage to the industries in preparing better material for entrance therein, an advantage that employers would be quick to perceive yet slow to bring about; but rather the recognition on the part of the public of a social obligation to better the opportunities for great numbers of young persons to enter upon more substantial careers.

The development of these schools has been largely confined to the eastern Atlantic states, particularly Massachusetts, New York, New Jersey and Pennsylvania. In New York state there were twenty-four such schools in 1920–1921, scattered throughout the different cities of the state. There were five in New York City, four in Buffalo, three in Rochester and lesser numbers in the smaller cities. Table 1 gives the unit trade courses maintained in these schools and the enrollment for 1921–1922.

Table 1 Enrollment by Trade Courses in Unit Trade Schools of New York for 1921–1922

Name of Trade Course	Enrollment Boys	Girls	Totals	Number of Schools Offering Courses
Electrical work	1636	0	1636	13
Machine shop	1299	0	1299	19
Auto repairing	1111	0	1111	8
Cabinetmaking-carpentry	689	0	689	15
Printing	477	0	477	12
Machine drafting	422	0	422	8
Patternmaking	304	0	304	9
Sheetmetal	226	0	226	8
Architectural drafting	159	0	159	2
Plumbing	146	0	146	4
Commercial design	115	0	115	2
Sign painting	72	0	72	1
Bookbinding	44	0	44	1
Painting and decorating	27	0	27	1
Forging	20	0	20	1
Industrial chemistry	16	0	16	1
Power-plant operating	16	0	16	1
Shoemaking	12	0	12	1
Dressmaking	0	1250	1250	1
Millinery	0	466	466	1
Garment-machine operating	0	190	190	1
Novelty, lamp shades, sample mounting	0	59	59	1
Garment design	0	29	29	1
Straw-machine operating	0	28	28	1
Flowers and feathers	0	27	27	1
Manicuring and shampooing	0	24	24	1
Embroidery-machine operating	0	18	18	1
Cooking	0	13	13	1
Totals	6791	2104	8895	

This type of school would appear to have become a stable element in the educational system and may be expected to assist materially in equipping a considerable number of boys and girls entering the industries with greater industrial intelligence, greater understanding of industrial processes, and greater interest in industrial careers.

Secondary Technical Institutes

A group of schools, small in number but performing most important work in mechanical and electrical fields, have been developed in various parts of the country in the last thirty years. These schools offer a technical training above that of the trade school and below that of the engineering school, aiming, in other words, to equip the technical expert, designer, inspector, tester, overseer, shop superintendent and power-plant superintendent, in short, the non-commissioned officers of industry. Prominent among these schools are Pratt Institute, certain departments of the Carnegie Institute, the Ohio Mechanics Institute, the Rochester Mechanics Institute, the Lewis Institute, the Wentworth Institute, and the Dunwoody Institute. Such schools comprehend courses in machine construction, electrical construction, industrial electricity, steam and electrical power-plant practice, foundry management and operation, machine design, industrial chemistry and courses called industrial mechanical engineering and industrial electrical engineering. The courses generally extend two years in length although in certain schools they carry beyond this time. It is to be hoped that this type of school will develop considerably further in our country. It has a task to perform purely its own and one of extreme value to industry and engineering.

Technical High Schools

A number of schools aiming to fulfil the office of secondary

technical schools have been organized under public administration in the last 20 years. The manual training schools which developed rapidly in the United States between 1880 and 1900 did not contribute, as they were expected, trained workers to the industries, and attempts have been made to convert some of these schools into technical high schools having the distinct purpose of preparing pupils for industrial leadership, that is, for positions in industrial life requiring skill and technical knowledge and of greater importance and responsibility than those of skilled mechanics. The weakness of such schools, considered from the standpoint of the productive or operating industries, lies mainly in the fact that they neither require practical experience before entrance nor provide parallel experience as in the case of coöperative schools. As a result their graduates have mainly entered drawing rooms and other white-shirt occupations in industry or else, to a considerable extent, gone on to engineering schools. One of the functions for which these schools seem relatively well fitted is that of preparing young persons for entrance into the field of industrial chemistry.

Cooperative Schools

The coöperative plan by which the students spend half their time at work in industrial establishments and half in school, and which was first highly developed in the engineering department of the University of Cincinnati, has since been applied to students of high-school grade. This plan differs from the part-time plan in some important respects. In the first place the student body consists of enrolled high-school students and not of young workers already employed in commercial establishments. In the second place the larger amount of time spent in school allows both general and technical education to be carried much further. This type of school is maintained in some 47 cities in our country at the present time but its exact place in the scheme of industrial education is not yet clearly defined. Whether, on the one hand, any considerable number of those aiming at and fitted for regular mechanics' work in trades will be drawn to such schools, or whether, on the other hand, such schools will develop capacity for training leaders of the foreman and expert type still remains to be seen.

It is to be doubted that many high school students can be counted upon to enter manual occupations in the industries. We must recognize that the ideals of the homes from which come the large body of high-school students are directed distinctly away from such occupations for the sons and daughters and it would seem clear that the contributions of the high school to the field of industry must be found in supplying young men with the basis of a good education who are fitted after a further period of practical experience to attain positions of at least subordinate leadership.

From this point of view it is evident that coöperative industrial classes in the high schools cannot be expected to reach large numbers, but on the other hand it is also evident that such classes give promise of developing a type of young man well fitted to find an important place in the industrial order.

Foreman Training

Considerable development has been made in the past two years in the very important field of foreman training. A valuable contribution was made to the subject by a report published in 1920 by the Federal Board for Vocational Education by Charles R. Allen.[1] The work has been forwarded both by the Federal Board and by state authorities. In the former case the work has been promoted in three principal ways:

First, by national conferences of four weeks in length held during the last two summers at Minneapolis, attended by state representatives and representatives of industrial concerns, in which courses for the training of conference leaders were developed.

Second, demonstration courses or conferences conducted by agents of industrial education service in industrial plants. A large number of these conferences have been held in various parts of the country in the last two years. The programs have almost uniformly covered a period of two weeks and foremen have been in attendance at the conference either five or six hours a day during working hours.

Third, through publishing the results of research and experimental work and distributing this material to persons in the states and industries who are concerned with the problem of foreman training.

Programs of foreman training have also been developed by the states of New York, Missouri, Pennsylvania, Nebraska, Virginia, Georgia, and Ohio. This work is generally conducted by some educational institution of recognized standing under the supervision of the special state agent in charge of this type of work. Most state work is conducted in industrial plants during the regular working hours.

The development of this work promises to be one of the most important as yet undertaken by the schools. It has been dealt with not on the conventional basis of school instruction but largely through conferences in which the chairman or leader seeks to make his points by drawing out the experiences of the foremen present. Assistance in this field has been eagerly sought for by employers and if the work is carried out with the same judgment and care that have marked its beginnings it may well prove of invaluable service to industry.

Results of Federal Vocational Education Act

The passage of the vocational education bill, commonly called the Smith-Hughes Act, by Congress in February, 1917, placed the the whole matter of vocational training in schools upon a new basis. By the provisions of this act, which went into effect July 1, 1917, one-half the cost of the salaries of teachers of trade and home economics subjects and of teachers and supervisors of trade and agricultural subjects is paid by the Federal Government up to the limit set by the government appropriation and one-half is paid by the state or local community. The state or local community or both must meet all the other expenses of the schools including site, plant, equipment and other expenses together with the salaries of teachers of academic subjects.

To take advantage of its provisions the act requires the state through its authority to accept the provisions of the federal bill, designate or create a state board of control and designate the state treasurer as custodian of the funds. All moneys disbursed by the board are paid by the state treasurer to approved schools as reimbursement for expenditures already incurrred. Federal money is paid to local communities only after their work has been approved by the state board on the basis of the federal act.

Schools entitled to the benefit of the federal grant are: (*a*) all day schools in which half the time must be given to actual practice of a vocation on a useful or productive basis; (*b*) part-time schools or classes for workers over fourteen years of age; (*c*) evening schools or classes for workers over sixteen years of age.

In order that states may receive federal aid, teachers, supervisors, and directors must have the minimum qualifications, the plant and equipment must meet the minimum requirements, and efficiency of instruction must meet the minimum standards as set up by the state board and approved by the federal board.

The Federal Board for Vocational Education is composed of the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Labor, the United States Commissioner of Education and three citizens appointed by the President by and with the consent of the Senate, one to be a representative of manufacturing and commercial interests, one a representative of agricultural interests, and one a representative of labor.

The effect of the Federal Vocational Education Act upon the development of vocational education since its enactment has been very marked. Prior to the passage of the act only seven states in the union had enacted laws recognizing vocational education as a part of the public school program and appropriated funds to assist local communities in developing this type of work. Before January 1, 1918, every state in the union, through official action by the legislature or by the governor, had accepted the provisions of the Federal Vocational Education Act. Every state during the same period submitted plans for accepting the provisions of the federal act and the rulings of the Federal Board for Vocational Education as regards standards and methods. Every state also set up a definite State Board for Vocational Education and organized itself for the discharge of its duties under a responsible staff. The number of states employing supervisors of trade and industrial education in 1916 was seven, in 1921 was forty-five.

[1] Staff Federal Board for Vocational Education, Washington, D. C.

In 1916 the total appropriations by states for vocational education was $1,300,510.15 and expenditures by local communities was $2,118,208.96, making a total of $3,418,719.11. In 1921 the total state appropriations were $5,595,956.78, those by local communities $9,489,809.01, and federal appropriations in the same year were $2,949,850.57, making a total of $18,035,616.36. The most significant element in these figures is the increase of local appropriations largely brought about by the stimulus of federal grants. Enrollment in federally aided vocational schools increased from 164,186 in 1917 to 323,028 in 1921.

The publications prepared by the Federal Board for Vocational Education upon various problems of vocational education and administration have been extremely helpful to those engaged in the field.

The value represented by the great expansion of vocational education under public control undoubtedly should not be entirely measured by figures of enrollment or by money expended. During the rapid development of the last few years, some of this work unquestionably has not been entirely effective or well done, as it has not always had the benefit of thoroughly competent instructors or supervisors. Like other educational work under public control its character is largely dependent upon the quality of personnel that is represented in the state departments of administration and by the local supervisory officers. It would seem to be a fact, however, that in most of the states the men occupying these positons represent a new type of educator, a type practically minded, generally possessed of some measure of practical experience and characterized by energy, initiative, and forward-looking vision.

Machinery has been set up and a large personnel developed for a vastly important work and if the results of this work, the policies pursued, and the quality of organization represented can receive both criticism when deserved and encouragement when merited from practical men and in particular from men of engineering status, the possibilities of sound and competent development of this phase of industrial education will be greatly increased.

The foregoing review of the present status of the many types of industrial education proves that such education has already advanced in a truly remarkable way and promises much for the future. An attendance in trade extension courses in New York alone of over 100,000, with approximately 325,000 studying in federally aided vocational schools supported by appropriations of over $18,000,000, together with a record of over 4,000,000 students in the United States having completed correspondence courses, will suggest much to the lay mind.

Director Moyer gives a clear and valuable survey of existing facilities for correspondence instruction and shows how employees of the industries may best secure the advantages thereof. That these advantages may be the greatest, each industry should coöperate with the university-extension agency in its state and secure for its employees the additional personal instruction furnished when correspondence instruction is applied for by groups, and the consequent formation of what are called extension classes.

Dean Sackett's description of existing apprentice and shop schools will prove of value to every industry which has under consideration the starting of such a school in its own establishments. The associated analysis by Dean Sackett of the difficulties to be overcome is not the least important part of his contribution.

Director Richards deals with the organized trade schools and vocational education of industrial nature in the public schools. Evening schools, part-time schools, unit trade schools, secondary schools and high schools for technical training, and coöperative schools of vocational nature are all included within his theme and receive his illuminating analysis. A very important part of the paper is his summary of the results of the Federal Vocational Education Act.

The Committee is of the opinion that not only are these papers which it puts forward as its report of much value in themselves, but that a full discussion of the subjects treated therein by the members of this Society who are directly connected with manufacturing will result in an additional improvement in the practice.

W. W. Nichols, *Chairman,*
Committee on Education and Training for the Industries.

Discussion

The previous reports were presented at the A.S.M.E. Annual Meeting Session held December 5, 1922, with W. W. Nichols, Chairman of the Committee on Education and Training for the Industries, in the chair.

In discussing the section devoted to extension and correspondence schools, Dane A. Carpenter pointed out that, while instruction by correspondence is as old as written language, the large field for this work is evident from the fact that only 13.9 per cent of the pupils entering grammar school graduate from high school and only 2.3 per cent graduate from colleges or universities. Even though colleges increase their registration at the present rate they will be able to handle only a small fraction of the high-school graduates. Mr. Carpenter expressed the belief that the disadvantage commonly mentioned in connection with correspondence teaching, namely, lack of personal intercourse between teacher and pupil, and pupils in schools, had been greatly overstressed. He emphasized the fact that the merit of any correspondence institution depends upon inspirational effort, adequate textbooks, and educational service. He agreed thoroughly with Dr. Hollis, who, in his introduction to Dr. Moyer's paper, stated that the strength of the correspondence school was its ability to employ the very best talent in the preparation of the textbooks. D. B. Preston told of the work being carried on by the Extension Division of the United Y.M.C.A. schools. The standard course which is being carried on by the Y.M.C.A. schools in class rooms of various manufacturing institutions throughout the country is also being conducted by the Extension Division by correspondence. The Executive Division instructors who direct the lessons and check and compare results have found that in almost every case the work of the Extension Schools is superior to that of the class-room students.

In closing his discussion, Dr. Moyer stated his belief that our high-school education should be changed so that the students would be encouraged to take a smaller part of the high-school work and finish their education by night-school study, in extension schools, or by correspondence schools.

In his discussion on the second subdivision of the report, that devoted to school for apprentices and shop training, George M. Basford stressed the importance of convincing the higher executives of the organization that men can be trained and can be used after training. Only when executives look inside their own organization for the man they want and for the man they themselves have made, can training in the industries and by the industries be successful.

J. C. Wright emphasized the words of the previous speaker and assigned to the engineers of the country the responsibility for leadership in securing a greater understanding of the need for industrial training. He asked for the moral support and active assistance of the engineering profession for the Federal Board for Vocational Education. Frank B. Gilbreth also supported the remarks of Mr. Basford as to the importance of securing understanding by executives of the need for industrial training, especially that type which recorded "the one best way."

J. P. Brown, F. P. Anderson, James A. Moyer, W. H. Sawtell, and F. E. Matthewson discussed the merits of the high school and its place in preparing for industry. In closing the discussion Dean Sackett reëmphasized the marked change in the attitude of management toward education as exemplified by the period preceding the war in comparison with the war period and since the war. He stated it was his belief that one of the best contributions of shop training is the bringing together of the management and the men into closer relationship, and if this relationship permits the discussion of the fundamental principles of sound industry, a great deal has been accomplished. Arthur L. Williston stressed the importance of grouping in the preparation and training of the workers of industry. He suggested that each member of the Society attempt to induce the organization with which he is connected to record the facts regarding the extent to which workers were devoting themselves to self-improvement in correspondence schools or part-time schools. Dr. Hollis stated that all education must tend toward fitting young men to make a living that they might not become public charges and to use intelligently the spare time that they can gain by reduction of hours of labor.

New Factors Influencing the Design of Woodworking Machinery

By SERN MADSEN,[1] CLINTON, IOWA

Such factors as the adoption of high-speed steel, demands of greater economy, power and speed, the use of ball bearings, and the direct application of the electric drive, necessitate new standards for woodworking machinery. The author discusses these factors, summarizes the problems of driving and fitting cutter heads, and tells how ball bearings and electric motors overcome many of them. The savings in power resulting from the use of ball-bearing motor-driven arbors are pointed out, and the paper includes tables of synchronous-motor speeds and motor speeds available with two and three frequencies.

WOODWORKING machinery, which has been considered standard for many years, is now passing through a period of revolutionary design. Among the many factors which are causing this change may be mentioned: (1) Adoption of high-speed steel and improved cutter-head design; (2) the demands for greater speed and more economical production; (3) the use of ball bearings for high-speed arbors; and (4) the direct application of the electric drive, first to individual machines, and now to each individual head.

It is the purpose of this paper to show how these factors are greatly influencing and determining the type of woodworking machinery of the future. The machines considered, for the most part, will be those used in the sash, door, and millwork industries,

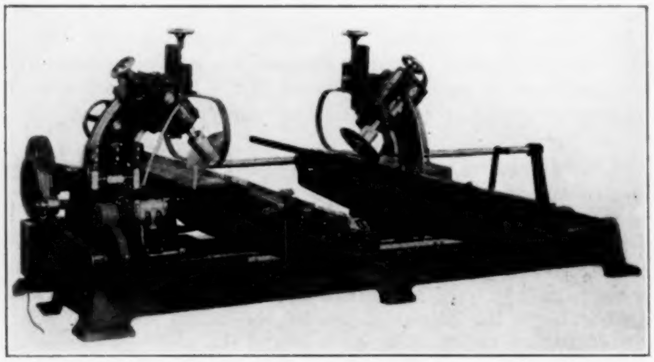

FIG. 1 DOUBLE CUT-OFF SAW

(The motor applications to this machine illustrate how well motors can be used to apply power to arbors adjustable to various angles. These motors are built to carry the entire bearing load in the end plates of the motor itself. The bearings are of the single-row deep-groove type with about 18 or 20 $^5/_{16}$-in. balls. Grease lubrication is used.)

and these represent quite completely all the machinery used in the remanufacture of lumber into finished products.

Practically all woodworking machines perform their work by a process of milling, abrading, boring, or pressing. By far the greater number perform shaping operations and use milling or cutter heads of various shapes and forms. Discussion of this class of machines, alone will be fairly representative of the entire line.

Cutter Heads

In the early days of the development of the woodworking industry only the very choicest lumber was used. Preferably softer woods and the straighter-grained materials went into articles requiring much shaping and fine finishes. With such materials the old-style square cutter head did remarkably well. Having a hook with an angle of 45 deg. it cut and planed well with a minimum of power required. The growing scarcity of softer wood resulted in the necessity of working up not only the harder woods but the crooked-grained materials as well. Coupled with this came the demands for greater speed. The square head, though still used to some extent, had a tendency to tear due to its great hook. The remedy was to back bevel or reduce the cutting angle of the bits. Two difficulties were encountered: carbon steel would not stand up, and the power required to drive the heads increased. The adoption of high-speed steel remedied the one difficulty but did not reduce the power.

The improved work and absence of tearing resulting from more of a scraping cut has so influenced cutter-head design that now it is not unusual to find cutter heads with as little as 5 or 10 deg. rake instead of the original 45 deg. With cutters having so little angle the shavings are broken up and come off more curly. In some cases the power required may be reduced by setting the cutters at a sufficient angle to produce a side-shearing cut.

More Power and Speed

When it was found that high-speed steel would stand the scraping cut it became almost universal practice to apply more power and turn out more work. Milled-to-pattern bits and round heads with their high-speed-steel bits were developed; as all of these could withstand greater centrifugal stress, higher speeds could be used in an endeavor to obtain more knife cuts.

Here again it was found that more power and more speed meant wider belts, larger pulleys, and excessive belt speeds. At somewhere around 4000 r.p.m. we begin to experience more or less trouble in transmitting power to the cutter heads by means of belts. Centrifugal force tends to reduce both the grip of the belt and the arc of contact on the cutter-arbor pulley. The high belt speed tends to whip it to pieces and necessity for greater tension strains the belt. Heating up of the pulleys tends to increase belt slippage and further aggravates the trouble.

Whether influenced by these considerations or not, belt-driven machines have not generally been designed to operate at more than from 3600 to 4000 r.p.m. The use of two driving belts, one at each end of the cutter-head arbor, has enabled some machines to operate at the higher speeds.

Since designers were limited in the direction of increased cutter-head speeds and since it is practically impossible to set two or more knives or bits to cut exactly the same, it was necessary to find some means of securing a greater number of uniform-depth knife cuts per revolution of the cutter heads. Larger-diameter cutter heads were adopted and more bits inserted, but no matter how carefully set up, generally but one bit actually does the finish cutting and leaves "revolution marks" on the work. The axis of rotation of a cutter head at high or operating speed is never the same as at rest. Slight unbalance causes a corresponding "throw" at high speed which may be sufficient to cause one bit to cut deeper than the rest. We may be able to make all bits cut, but seldom will they "finish" the same depth. A difference of 0.001 in. or less is very apparent on feeds greater than 1 in. for each 15 revolutions of the cutter head.

The problem of getting all bits to cut has practically been solved by jointing or dressing them to even length with a stone while the head runs at cutting speed. High-speed steel is much more satisfactory where jointing is necessary. If the "heel" produced by jointing varies too much on the successive bits or cutters the effect is as bad as though one were longer than the others. In spite of all these improvements there are still cutter heads that cannot be jointed and we must depend on higher rotative speeds.

Having summed up the various problems of driving and fitting cutter heads, it is interesting to note how admirably ball bearings and electric motors overcome many of them. The belt drive, at its best, subjects the bearings to more or less pounding and vibration and also causes a tremendous amount of side pull and friction owing to belt tension.

A motor direct-coupled to the arbor overcomes some of these

[1] Superintendent of plant equipment, Curtis Companies, Inc. Mem. Am.Soc.M.E.

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objections, but still involves difficulties with couplings, alignment, etc., besides requiring considerable space.

A practice which is constantly growing in favor is to "build the motor in" so as to make the motor shaft and cutter arbor identical. While such an arrangement is ideal in providing high speeds, even, steady torque, and an abundance of power, it still involves some problems in bearing design. On this one point there is still no approach toward standard construction. Some machine builders mount the motor entirely outside the main arbor bearings and let the rotor run on an overhung shaft with no bearings in the stator whatsoever. This construction works very well on lower speeds up to possibly 1800 r.p.m., but its use is questionable on speeds of 3600 r.p.m. and higher.

Attempts have been made to improve this construction by use of an outer bearing in the motor, but best practice greatly favors the use of only two bearings on any high-speed arbor wherever possible.

Another method which appears to meet with more approval is to build the motor frames exceedingly strong, with heavy bearings and as great overall length as practical.

One machine builder has adopted a construction involving a heavy yoke with heavy bearings at each end and mounting the stator on the yoke. While this is an exceedingly heavy construction, it does remove nearly all mechanical stress from the motor frame itself.

Still another method of construction used by a prominent machine builder consists of mounting the arbor in the usual bearings at the ends of a heavy yoke. The motor complete is located on the arbor between these bearings, and ball bearings in the end plates maintain clearance between rotor and stator.

These varied types of construction show that no definite best plan has yet been decided upon. The essential problem is to provide for:

1 Rigid bearings without end play for the cutter-head arbor
2 Bearings that will maintain, or are adjustable for, clearance between stator and rotor
3 Bearings that will stand up at the higher speeds of 5000 to 7000 r.p.m.

Ball Bearings

In nearly all of the designs ball bearings are used and are meeting with very good results. Types of bearings vary from the double-row self-aligning type to the deep-groove single-row. The latter has the preference where end play is to be prevented, but the former is much preferred where radial load is predominant. It is quite important that end thrust be cared for at only one bearing and that all other bearings be free to move longitudinally with the shaft as it may expand or contract. One manufacturer uses a well-lubricated bronze thrust bearing to resist end play in one direction, while one of the ball bearings meets it in the opposite direction.

In the usual construction the inner ball race is locked to the arbor while the outer race is free to creep or turn gradually. Bearing manufacturers claim this is desirable in order to distribute gradually the wear to different surfaces of the outer race. Instances are known, however, where this has gradually worn the retaining case to the point of objectionable looseness. Proper lubrication also seems to be a problem worthy of further study. Ordinarily hard-grease cups are used but better, more nearly fool-proof devices, are needed. Automatic circulating-oil lubrication seems most desirable for high speeds. Prevention of oil leakage into the motor windings is a difficult problem to solve successfully.

The life of ball bearings at high speed is something not yet well determined. It is generally agreed that they do not need replacing so often as babbitted bearings. Very few properly designed bearings fail short of what is considered satisfactory service.

Even with the possibility of an occasional bearing failure, there nevertheless seems to be a general feeling among users that it is far cheaper, both in time and money, to replace an occasional ball bearing, than to replace babbitted bearings giving a like service. A prominent designer advances the belief that the average life of bearings operating at 3000 to 7200 r.p.m. will be about three years, and that at speeds slower than this they will last indefinitely.

Power Requirements

The savings in power resulting from the use of ball-bearing motor-driven arbors is little short of amazing. Tests of motorized and belt-driven equipment seem to indicate that we may hope to save nearly 50 per cent of the power now used for driving such machines as molders, stickers, planers, sanders, etc. This is cheering news in the face of the facts brought out earlier in this paper that the later types of heads designed to do better work do require more power to drive them. By this happy coincidence it may be possible for woodworking plants to keep their power requirements from continually mounting higher.

While it is encouraging to know that the total power requirements of a woodworking plant can be reduced by the substitution of ball-bearing motor-driven machinery, there nevertheless are other new problems that must be considered. In order to motorize a machine completely it is necessary to make the aggregate horsepower of all the individual motors much greater than the average power consumption of the machine. Each motor must be enough oversize to care for extreme or overload conditions. Oversize or underloaded motors operate at a lower power factor. It is therefore necessary to provide either oversize generators or to install synchronous condensers. In a new layout perhaps the larger generator is preferable, while for equipment already installed the synchronous motor offers the best solution.

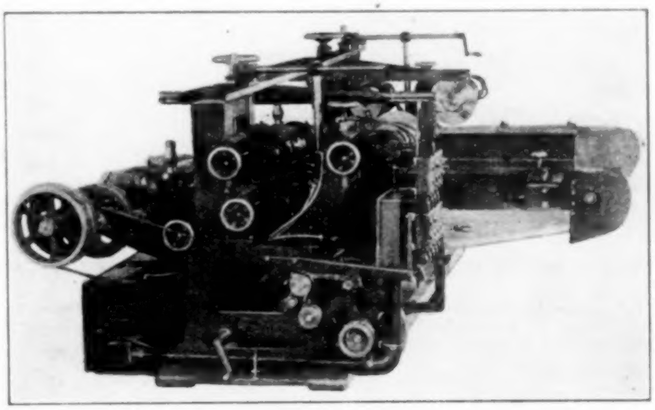


Fig. 2 Double-End Cut-Off Saw

(This machine uses nine motors and illustrates well how belt and gear drives are being eliminated. To meet the limitations of small space even the motors have to be built with small diameters and increased in length. Motor controls on this class of machines provide that the motor driving the feed will stop automatically if for any reason any one of the cutter-head motors should stop. Push-button control is being adopted almost exclusively.)

Higher Frequencies

In general, 3-phase 60-cycle current is standard for woodworking plants. This limits motor speeds not only to 3600 r.p.m. maximum but also to comparatively few other speeds. Frequency changers are now standard equipment with many electrical manufacturers, and they are generally installed as individual units to care for each new high-speed motor-driven machine as installed. This practice soon requires an undesirable number of extra units.

A problem which is already becoming acute is to determine the better practice of providing higher-frequency current, whether by frequency changers or by direct generation in the power plant; also how many frequencies should be available and which will give the most desirable range of motor speeds. Table 1 gives the available synchronous speeds for a wide range of frequencies. From this we can choose such combinations as are desired.

Assuming that 60 cycles will always be standard and that one other frequency is desired, Table 2 gives the additional motor speeds for 80 and 85 cycles. Of the two, 80 cycles gives the better range, but the maximum speed available may not be considered high enough. If the highest speed must govern, then 85 cycles is preferable.

If we wish to have three frequencies available we find that 60, 75, and 90 cycles or 60, 80, and 100 cycles give the best ranges of speeds with the most uniform steps. The combination shown in the left-hand half of Table 3 gives a most desirable range above 1080 r.p.m. and is probably preferable for direct connection of motor to cutter head arbors.

The right-hand half of Table 3 shows a combination of speeds that has fairly even steps all through and is especially even in steps

TABLE 1 SYNCHRONOUS MOTOR SPEEDS

No. of Poles	Number of Cycles 60	65	70	75	80	85	90	95	100	105	110	115	120
2	3600	3900	4200	4500	4800	5100	5400	5700	6000	6300	6600	6900	7200
4	1800	1950	2100	2250	2400	2550	2700	2850	3000	3150	3300	3450	3600
6	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2390	2400
8	900	975	1050	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800
10	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440
12	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
14	512	555	597	640	683	725	768	811	853	896	939	981	1024
16	450	487	525	562	600	637	675	712	750	787	825	862	900

TABLE 2 MOTOR SPEEDS AVAILABLE WITH TWO FREQUENCIES

(2- to 16-pole motors)

Cycles 60	80	Difference in speeds	Cycles 60	85	Difference in speeds
450			450		
		62			62
512			512		
		88			82
600	600		600		
		83			37
	683			637	
		37			83
720			720		
		80			5
	800			725	
		100			125
900				850	
		60			75
	960		900		
		240			120
1200	1200			1020	
		400			80
	1600		1200		
		200			75
1800				1275	
		600			425
	2400			1700	
		1200			100
3600			1800		
		1200			750
	4800			2550	
					1050
			3600		
					1500
				5100	

TABLE 3 MOTOR SPEEDS AVAILABLE WITH THREE FREQUENCIES

(2- to 16-pole motors)

Cycles 60	75	90	Speed Diff.	Cycles 60	80	100	Speed Diff.
450				450			
			62				62
512				512			
			50				88
	562			600	600		
			38				83
600					683		
			40				37
	640			720			
			35				30
		675				750	
			45				50
720					800		
			30				53
	750					853	
			18				47
		768		900			
			132				60
900	900	900			960		
			180				40
		1080				1000	
			45				200
	1125			1200	1200	1200	
			75				300
1200						1500	
			150				100
		1350			1600		
			150				200
	1500			1800			
			300				200
1800		1800				2000	
			450				400
	2250				2400		
			450				600
		2700				3000	
			900				600
3600				3600			
			900				1200
	4500				4800		
			900				1200
		5400				6000	

for speeds below 1000 r.p.m. This makes this combination especially desirable for direct connection of motors to exhauster fans where quite definite speeds are needed and which are not obtainable with the 60-cycle current alone. Everything considered, 60, 80, and 100-cycle currents seem to be the most desirable. This permits a start with 60 and 80 cycles as in Table 2 and later adding the 100-cycle current.

Another use of two or three frequencies for is driving feed motors. It also makes available a proper cutter-head speed to suit the work being done, a practice which is still quite unknown to the woodworking industry. One machine-building company already cares for this by using a multi-speed motor for driving the frequency changer, which indicates that variable cutter-head speeds may even now be on the way. It seems logical that different woods and different cutter heads should operate at different speeds for best results.

Power Generation

There are many ways of generating or converting power of different frequencies, such as:

1 Main generator, 60-cycle; others through frequency changes

2 Two or more independent units operating at different frequencies

3 One large prime mover with two or three generators on the same shaft.

In small plants the first method is undoubtedly to be preferred. Where only two frequencies are desired two separate units might be preferable, especially for larger plants. When three frequencies

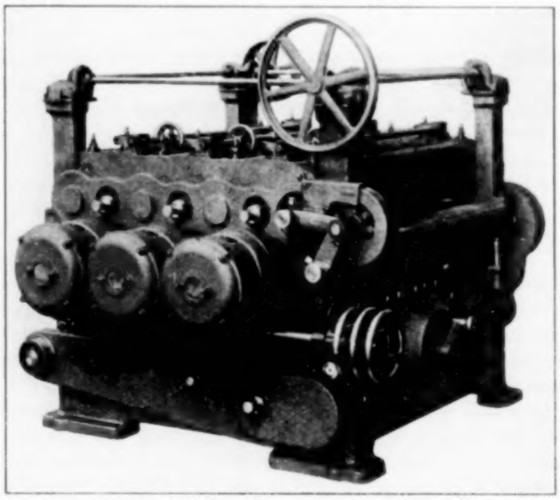


Fig. 3 Three-Drum Direct Motor-Driven Sander with Overhung Motor

(This design illustrates perhaps one of the most successful designs of motor application in which the motor is overhung. The stator is attached securely to a yoke which connects to two drum bearings, while the rotor is mounted directly on the projecting end of the drum shaft. This construction insures perfect alignment at all times, since all parts move as a unit. End oscillation of the drum is provided for by use of a rotor of slightly greater length. The usual drum speed, 1200 to 1800 r.p.m., is low enough to permit use of the overhung motor without an outside bearing.)

are desired it seems best to use at least two units and possibly to put two generators on one shaft.

Another solution may be in specially built generators with multiple windings. These are problems that are worthy of some thought. Each plant will have its own problems as to how large the capacity for current of each frequency must be. It would be desirable to have the higher frequency units arranged to operate at 60 cycles in emergencies. Nearly all woodworking machines can be operated with considerable variation in speed if necessary, in case of breakdown or emergency. Other considerations will be extra switchboards and power lines, but this part of the multiple system is not complicated.

This discussion has thus far dealt but briefly with these new factors in woodworking-machinery design, but it is hoped that it may point out the opportunity for standardization among machine builders in getting out this new line of electric machines. Among the items that may well be standardized may be mentioned the following:

1 Use of 3-phase 60-cycle 220-volt alternating current as the basic standard for power in woodworking plants

2 Adoption of either 40- or 50-deg. rating for motors; 40-deg. motors are decidedly to be preferred in woodworking plants

3 A definite choice of certain higher frequencies. The adoption of 60, 80 and 100 cycles is suggested

4 An attempt at standard design for motor mounting, arbor bearings, and motor-control apparatus.

The reason for such standardization is to simplify the amount of apparatus with which the woodworking-machine operators must be familiar. Simplicity and standardization will be greatly appreciated by the users and will contribute greatly to the development of this type of machinery.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Pulverized-Coal-Burning Central Station, Bruay Mines, France

By JACQUES BOYER

DESCRIPTION of an installation said to be one of the largest pulverized-coal-burning plants in Europe and which embodies several improvements as compared with general European practice.

Fig. 1 shows the pulverizing plant with a capacity of 180 tons of coal per day of 16 hr. It comprises two concrete coal bins located under a standard-gage track and intended to receive from the cars the coal as it comes from the mines. Two belt conveyors with a capacity of 25 tons per hour deliver the coal from these bins to two elevators which lift it to another bin over the grate of a rotating drying furnace. (This drying furnace is shown in the original article by a halftone not suitable for reproduction.) After drying, the coal passes through a magnetic separator which removes any particles of iron it may contain, and then is carried by two elevators to a screw conveyor (Fig. 2) which distributes it among three hoppers. From these it flows by gravity into three Simon-Carves ball crushers. The pulverized coal is then lifted by air suction and delivered by a blower into two storage bins, whence it can be fed by gravity as desired on to weighing platforms so as to check the amount employed each day by each furnace. From the weighing platform the coal is delivered to the proper furnaces by piping with an inside diameter of 100 mm. (3.9 in.).

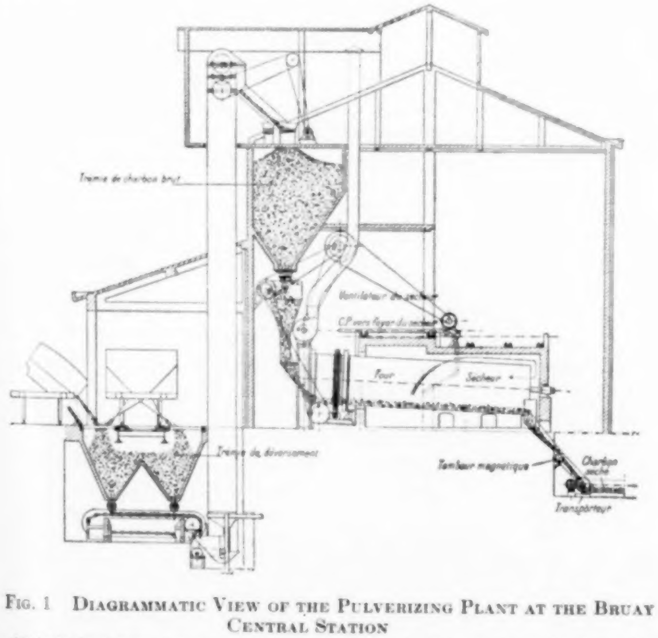


FIG. 1 DIAGRAMMATIC VIEW OF THE PULVERIZING PLANT AT THE BRUAY CENTRAL STATION

(*Trémie de charbon brut* = raw-coal bin; *trémie de déversement* = discharge bin; *ventilateur du sécheur* = drier blower; *C.P. vers foyer du sécheur* = conveyor belt delivering pulverized coal to the drier furnace; *four sécheur* = drier furnace; *tambour magnétique* = magnetic separator; *charbon séché transporteur* = dry-coal conveyor.)

As has been shown by Michel Sohm, chief engineer of the surface plant of the Bruay mines, the condition of the pulverized coal has an important bearing on its combustion. In order to carry the degree of fineness to which the coal is broken up as far as possible the crusher is equipped with a horizontal shaft provided with four sets of articulated handlike members working as hammers. This machine pulverizes coal in sizes 0.10 to 0.15 mm. (0.0039 to 0.0059 in.) both by friction and by percussion.

Furthermore, the dimensions of the combustion chamber of the furnace must be properly proportioned for a given fineness of coal. As a matter of fact it is easy to see that coarsely granulated coal will require a greater excess of air than an impalpable coal powder. Likewise, the length of time that the powder has to remain in the furnace in order to achieve complete combustion also depends on the size of its grains. Thus slaty coals, which are the hardest to pulverize, come out from the machine with a coarser grain and their velocity of ignition is clearly inferior to that of pure coal; they ignite at a greater distance from the tip of the burner, soften, and

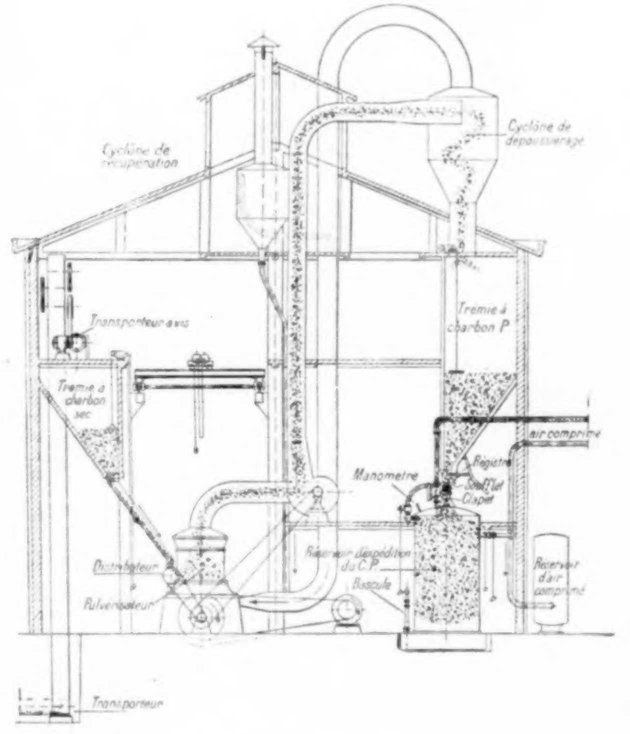


FIG. 2 DIAGRAMMATIC VIEW OF THE PLANT FOR THE STORAGE AND DELIVERY OF PULVERIZED COAL TO THE FURNACES

(*Cyclone de récupération* = recuperator blower; *cyclone de depoussiérage* = dust-elimination blower; *transporteur a vis* = screw conveyor; *tremie à charbon sec.* = dry-coal bin; *tremie a charbon P.* = pulverized-coal bin; *air comprimé* = compressed air; *régistre* = damper; *soufflet* = bellows; *clapet* = valve; *réservoir d'air comprimé* = compressed-air reservoir; *réservoir d'expédition du C.P.* = delivery bin of pulverized coal; *bascule* = weighing bridge; *distributeur* = distributor; *pulvérisarteur* = pulverizer; *transporteur* = conveyor; *manomètre* = manometer.)

clinker whenever the grains come in contact with each other, and in order to insure their complete combustion it becomes necessary to provide longer paths for their travel.

The above considerations explain why it is that as the hammers of the crushers wear away, the walls of the combustion chamber, the bottom parts of the lower passages, and the orifice of the injector become covered with slag. The reason is that unless the crusher hammers are renewed from time to time, the degree of fineness, which was fully efficient initially, ceases to be capable of providing for complete combustion. Moreover, variations in the degree of humidity have a notable influence on the output of the pulverizing equipment and on the regularity of flow of the pulverized coal either at its exit from the storage bin or through the distributor passages or burners. Hence the necessity of preliminary drying, which makes it possible to use all kinds of coal.

At the Bruay central station (Fig. 3) only dry coal ground to an impalpable powder is used. This coal is delivered by distributor fans into bins located in front of the furnaces. At the bottoms of these bins there are two controllers per boiler which distribute the fuel to the furnaces, while a low-pressure blower supplies each furnace with the air necessary for combustion. The air is mixed with the coal just before they enter the furnace. Various precautions have been taken to prevent the penetration of the pulverized coal into the crusher or engine rooms. It is said that these precautions have been of such a nature that the total loss in weight of coal from the time it is discharged from the cars to the time it is delivered to the furnace is less than 0.6 per cent. The controller distributors of the pulverized coal are equipped with a simple regulating device involving the use of a flywheel driven by a variable-speed motor, and this insures a regular supply of fuel to the furnaces.

As shown in Fig. 3, each furnace consists of a combustion chamber,

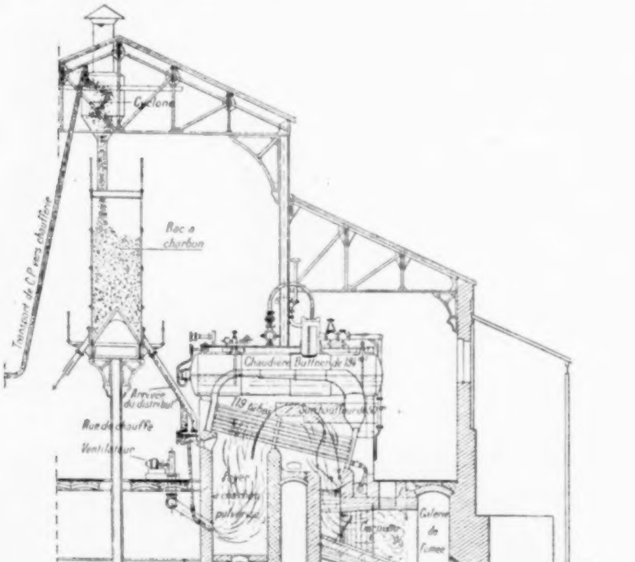


Fig. 3 Diagrammatic View of the Buttner Boiler Equipped for Burning Pulverized Coal

(*Cyclone* = fan; *transport de C.P. vers chaufferie* = conveyor delivering pulverized coal to furnace; *bac à charbon* = coal bin; *ventilateur* = blower; *arrivée du distribut* = distributor delivery line; *chaudière Buttner de 194m²* = Buttner boiler with 194 sq.m. heating surface; *surchauffeur de 50m²* = superheater with 50 sq.m. heating surface; *carneau* = flue; *foyer a charbon pulvérisé* = pulverized-coal furnace; *cendrier* = ashpit; *wagonnet a cendres* = ash car.)

separated by an arch from the slag pit, which latter is provided with a door that closes automatically. This arrangement facilitates the flow of the powdery or molten slags and also makes it possible for them to be raked into the monorail ash car shown in the drawing. The boilers with which the plant is equipped are of the Buttner make, each with 194 sq.m. (2087 sq.ft.) of heating surface, 119 tubes and a superheater of 50 sq.m. (538 sq.ft.) which give an evaporation of 3600 kg. (7935 lb.) per hour at a temperature of 275 to 300 deg. cent. (527 to 572 deg. fahr.).

The damper arrangement is such that the gases are forced to flow parallel to the walls—in other words, to pass over the entire width of the set of tubes. With the aid of a lever controlled from the front of the boiler the fireman can operate this damper which is made as a balanced butterfly valve. He can also communicate at any time by electrical means with the pulverizing plant, this arrangement being described in detail in the original article. One of the safety measures provided is a special device in front of the boiler which simultaneously and automatically stops both the pulverized-coal delivery and the fan blast, so as to extinguish the fire instantly when necessary under any of the furnaces. The purpose of this device is to prevent damage due to excessive pressure. The apparatus is electrical and consists of a current interrupter controlling both the pulverized coal delivery and the combustion air fans. (*La Nature*, no. 2543, Dec. 30, 1922, pp. 422–426, 6 figs., *dA*)

Short Abstracts of the Month

AERONAUTICS

Loening Flying Control. Description of a type of transverse airplane control which has recently been tested in flight. This control, called a lateral pressure equalizer, is mounted on the extreme tip of each wing.

A small section of the leading edge of the wing is extended out beyond the tip, to which is hinged a pressure-equalizer flap which is controlled through cables and levers by the pilot. It is claimed that with the new device the use of the trailing-edge aileron may be eliminated entirely.

Notwithstanding the fact that the pressure equalizer was tested under bad winter conditions, the ship was found responsive in overcoming wind puffs. (*Aviation*, vol. 14, no. 1, Jan. 1, 1923, p. 13, 1 fig., *d*)

AIR MACHINERY

Determination of Initial Pressure of Centrifugal Ventilators

Tests of Centrifugal Ventilators with Special Reference to Initial Water Gage, Henry C. Harris. It is claimed that very little progress has been made toward the discovery of the most suitable means of determining the initial water gage produced by the running of a ventilator. As a basis for calculation and experiment, the author took the practical example of a fan of large capacity installed to ventilate a mine of small capacity, namely, a Capell fan of the double-drum type 20 ft. in diameter and 6 ft. wide, with a single inlet 11 ft. in diameter and running at 90 r.p.m. The area of the shaft was 70 sq. ft., the area of the fan drift 72 sq. ft., and the area of fan inlet 95 sq. ft. Another series of tests were carried out on a Sirocco fan.

These tests, the results of which are given in the original paper

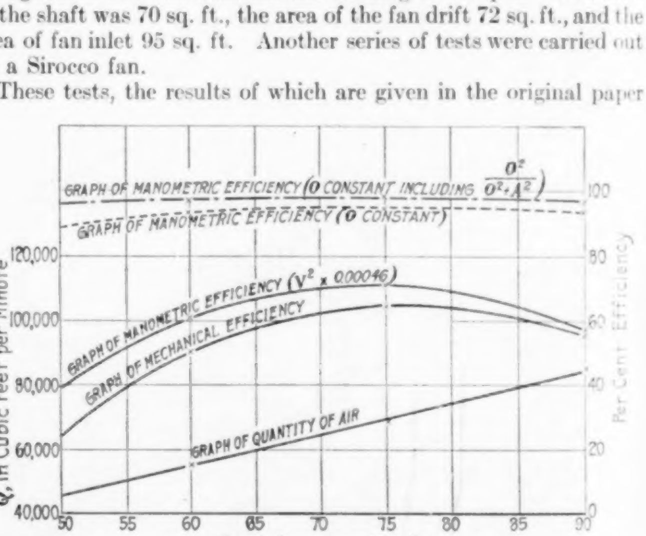


Fig. 1 Graphs of Results of Capell Fan Test

(Full lines for graph of manometric efficiency derived by conventional method; broken lines for those derived by the author's method.)

in the form of tables and curves, of which Fig. 1, for the Capell fan test, is reproduced, have led the writer to ask himself the following questions: (*a*) Why is the manometric efficiency of the ventilator so variable and so low? (*b*) Why does the fan give maximum results at 75 r.p.m. instead of at 90 revolutions as intended, etc.?

In trying to answer these questions the author found that a more consistent method than the conventional one of determining the initial water gage is necessary before any results of tests can be considered reliable, this being due to the fact that in most cases the velocity of the air on leaving the fan chamber which is used in determining the initial water gage, is not identical with the speed of the tips of the fan blades. The author therefore suggests a different method for determining the water gage, and by means of this method he derives the graph shown in Fig. 1 which appears to give results of a more uniform order. It is also claimed that on the basis of the manometric efficiency derived by this method the

maximum results at 70 revolutions instead of at 90 revolutions are consistent for a fan of large capacity ventilating a mine of small capacity. (Paper read December 9, 1922 before the Mining Institute of Scotland, abstracted through *The Iron and Coal Trades Review*, vol. 105, no. 2859, Dec. 15, 1922, pp. 884–885, 2 figs., *ep*)

ENGINEERING MATERIALS

RESEARCH WORK ON ALUMINUM, IRON, AND ELECTRON. Dr. of Engrg. Hanszel. Before the war aluminum alloys usually had a comparatively high tin content, namely, 6 per cent, and, in addition, 2 per cent of copper. Since these metals were scarce during the war, it became necessary to substitute other materials for them, zinc at first being preferred. It was, however, desired that the substitution of the alloying elements should not interfere with the machinability of the alloy and its compressibility. An alloy was therefore produced having an even higher tensile value than the previous standard alloys. It contained 7 per cent zinc, 0.8 per cent magnesium, and the remainder aluminum. Other similar alloys contained 10 per cent zinc and 0.7 to 1 per cent magnesium. These alloys when tested gave rupture strengths as high as 27,000 to 29,000 lb. per sq. in. For one of them (10 per cent zinc and 1 per cent magnesium) it is stated that the elongation was zero. The machinability of the alloys was poor. It was found, however, that the addition of 1 to $1^1/_2$ per cent of tin made them freely machinable. Pressed aluminum rods gave a metal of higher strength, though its machinability appears to have been poor.

The original article gives, among other things, curves showing the influence of adding manganese to aluminum as affecting the strength, elongation, and hardness of pressed round bars. (First of a series in *Canadian Foundryman*, vol. 14, no. 1, Jan., 1923, pp. 26–27, 1 fig., *g*)

Duralumin

AN INVESTIGATION OF DURALUMIN, Seibei Konno. Data of an investigation carried out at the Tohoku Imperial University, Sendai, Japan. The following conclusions have been reached:

1 In quenched duralumin, the softer the quenching the more the immediate effect of hardening increases, and its aging affect, as well as its final hardness, decreases. In a quenching in oil at 100 deg. or at higher temperatures the aging effect vanishes. On the other hand, the harder the quenching the more the immediate effect decreases, and the aging effect and the final hardness increase, their maximum values being obtained by quenching the alloy from 500 deg. in water.

2 The above effect of quenching is due to the dissolution of Cu and Mg compounds in Al, the process of dissolution or separation being very slow. Thus duralumin is in a somewhat hardened state, even if it is cooled very slowly from 500 deg.; perfect annealing is only obtained by heating the alloy at 350 deg. for one hour or more.

3 The quenching effects on the specific electric resistance of duralumin are very great and exactly similar to those on the hardness. Hence the specific resistance measurement is the most suitable method for the investigation of the hardening of duralumin.

4 The alloys of Al-Cu show by quenching an immediate effect of hardening, but the effect of aging only very slightly. Hence, the immediate effect is partly due to the dissolution of Al_2Cu in aluminum, but the principal cause of the aging effect of duralumin is not attributable to that compound.

5 In the alloys of Al-Mg which contain about one per cent of magnesium, the immediate effect of quenching is always very small, but the aging effect is as great as that of duralumin.

6 The aging effect, as well as the immediate effect of quenching the above alloys, is attributable to the dissolution of Mg_2Si in Al, but not of metallic magnesium; because, if magnesium increases beyond 1 per cent, the above two effects begin to diminish, and with an increase of above 3 per cent of magnesium, almost vanish; but an addition of both magnesium and silicon in the proportion of the compound Mg_2Si increases the same effects. A small quantity of silicon is always present in aluminum as an impurity.

7 The further addition of about 4 per cent of copper and a small quantity of manganese (up to about 0.5 per cent) to the alloys of Al-Mg increases the hardness, but not the aging effect. This alloy, usually called duralumin, has thus nearly the same aging effect as the alloys of Al-Mg.

8 From the specific resistance-temperature curves for quenched duralumin, we conclude that a quenched alloy is tempered at two steps, beginning at 210 deg. and 280 deg., respectively. The first step in the curves is due to the partial separation of Al_2Cu, and the second to that of Mg_2Si.

9 The quenched duralumin expands at room temperature as the aging proceeds, as in quenched low-carbon steels.

10 The above effect of quenching and the accompanying change in the physical properties of duralumin are exactly similar to those in severely quenched carbon steels. Hence we can easily explain the hardening of duralumin by Prof. K. Honda's theory of the hardening of steels.

The paper is accompanied by numerous curves and photomicrographs. (*Science Reports of the Tohoku Imperial University*, First Series, vol. 11, no. 4, Sept., 1922, pp. 269–294, 6 figs., 9 plates, *eA*)

FUELS AND FIRING (See Motor-Car Engineering)

HYDRAULIC MACHINERY

Chain-Type Water Elevators—Tests

TESTS OF CARUELLE WATER ELEVATORS. These water elevators, also called "Chaine-Helice," have been described in *Engineering*, vol. 98, 1914, p. 40, and are used mainly for raising water from open wells to the ground level.

The device consists of belts made up of strips of sheet aluminum alloy bent so as to form a series of triangular cells, the cells being riveted to a flexible supporting element, which, in the case of the smaller sizes, is a band of aluminum bronze. In the larger sizes balata belting is used to support the aluminum cells, a number of which are placed side by side. Large driving and jockey pulleys are used with these belts in order to reduce the bending to a minimum and grooves are turned in both pulleys to clear the rivet heads so that the latter are not worn away. A feature of this device which is particularly useful in the case of hand-driven installations is that they remain filled with water when stationary and if a ratchet is provided to prevent the belt from running back, due to the weight of the entrained water, delivery will commence as soon as the belt is set in motion. This is important with deep wells pumped intermittently at frequent intervals.

The tests were carried out by Sir Alfred Chatterton of the Indian Public Works Department and Arthur S. Collins, City Engineer of Norwich. In these tests two belts were used, the lifting elements of one measuring $^7/_8$ in. wide and $^5/_8$ in. deep, and those of the second $1^5/_{16}$ in. wide and 1 in. deep. The aluminum-bronze bands to which the elements were riveted were 1 in. and $1^3/_8$ in. wide, respectively, and in both cases the pitch of the triangular cells was $^1/_2$ in. The drive was by means of a leather belt from an electric motor, so arranged that the torque exerted could be measured. The lift in all cases was 152 ft. 6 in.

The results are given in diagrams in the original article. With the smaller belt a maximum net efficiency of 95 per cent was obtained with a linear speed of about 7 ft. per sec., but the efficiency fell off rather rapidly as the speed increased. In the case of the larger belt the maximum efficiency reached was practically the same, but was maintained over a wider range of speeds, only falling to 85 per cent at 13.4 ft. per sec. The maximum overall efficiency with the larger band was much higher than that obtained with the smaller band, the former reaching over 74 per cent and the latter about 58 per cent. Owing to the short distance between the centers of the driving and driven pulleys, rendered unavoidable by the existence of buildings close to the wall, a very tight belt had to be employed. This absorbed an undue amount of power and materially reduced the overall efficiency in both cases.

The tests have also shown that the larger belt gives a much wider range of deliveries with good efficiency, the maximum efficiency being reached at about 950 gal. per hr.

Another series of tests was made by the same authorities with the water-elevating belt made up of four sets of cells of the larger size of the two above described, riveted on to a balata belt. Here it was found that to obtain the highest efficiency with water elevators of this type, it is important that the immersion of the jockey pulley should be only sufficient to allow the belt to fill completely, a condition which would not always be complied with in practice.

It is claimed, however, that the advantages of simplicity, reliability, and general good efficiency are more than sufficient to compensate for this drawback. (*Engineering*, vol. 114, no. 2973, Dec. 22, 1922, pp. 770–771, 5 figs., *e*)

INTERNAL-COMBUSTION ENGINEERING (See also Motor-Car Engineering)

Ripert Motor with Steam Chamber in Head

THE RIPERT MOTOR, M. Grison. It is claimed that the following conditions, if satisfied, would improve the Diesel engine when operating on heavy oils and, in particular, would make it more flexible.

First, introduction of the oil into pure air not only at the dead center but ahead of it, namely, toward the end of the compression, in order to obtain a vaporization and diffusion of the oil through

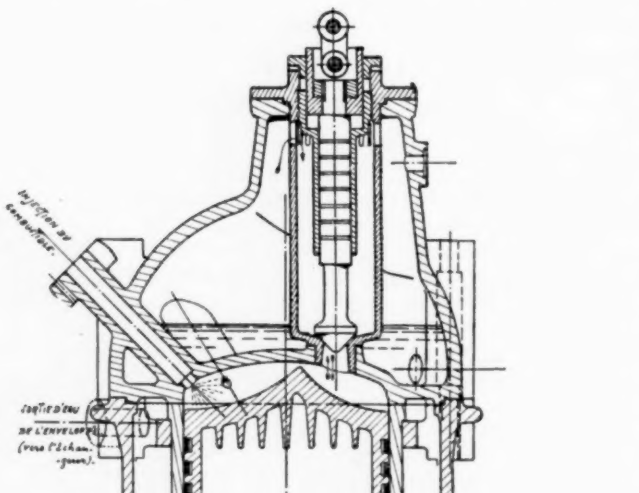


FIG. 2 RIPERT OIL ENGINE
(*Injection du combustible* = fuel injection; *sortie d'eau de l'enveloppe* = exit of water from jacket; *air frais* = fresh air; *eau fraiche* = fresh water.)

the air during the heating of the latter. The fuel being introduced during compression, the atomizer meets with only a relatively low pressure in the cylinder. It therefore works more efficiently. The fuel injection takes place without air injection, which eliminates the unfavorable refrigerating action of the latter. This of course makes the high-pressure compressor together with its appurtenances unnecessary.

The second condition is that the compression should continue up to the dead center, and hence a temperature should be attained close to that necessary for spontaneous ignition. As the fuel has already been distributed through the entire mass of the air and heated with it at the same time, the ignition can take place at the dead center throughout the whole charge simultaneously and have all the characteristics of an explosion.

During combustion a certain amount of water vapor should be introduced into the cylinder both because of its influence on the gas and on account of the well-known catalytic effect which assists the combustion of the heavier particles of tar oils. The steam helps to prevent the formation of coke deposits and improves the lubrication of the cylinder and hence the mechanical efficiency. With accelerated combustion and assured cooling it would not be necessary any longer to induct into the cylinder as great an excess of air as in the Diesel engine (thirty times the weight of the oil), which would increase the volumetric efficiency. Finally, the possible increase in the revolutions would tend to reduce the weight and first cost of the machine.

It is said that the Ripert motor (Fig. 2) was designed with the view of realizing as completely as possible the foregoing theoretical considerations. The drawing shows a two-stroke-cycle motor. The construction differs from that of the Diesel engine solely in the cylinder-head arrangement, which, in the Ripert motor, forms a kind of boiler. It is supplied with water in such a manner as to maintain automatically its internal temperature at about 250 deg. cent. (482 deg. fahr.) and the steam pressure at 30 kg. (428 lb. per sq. in.) approximately, although in both cases higher values may be employed.

Water feeding is effected by means of a small pump whose output is automatically controlled by a thermostat. This pump is independent of the speed of the motor. The water may be taken from the cylinder jacket and preheated by exhaust gases before being fed into the cylinder head, where it is superheated to the necessary extent. This plan is used, however, only with large motors. There is no trouble in maintaining a certain level of water in the cylinder head. The boiler in the head communicates with the combustion chamber in the cylinder by means of a valve.

The Ripert motor may operate with or without steam admission. If it is operated without steam admission when the piston is at its lower dead center, air is supplied to the cylinder either by crank-case compression or by a special pump. About the middle of the compression stroke or somewhat later heavy oil is introduced by solid injection. The temperature is then sufficient to vaporize the atomized oil and prevent its precipitation. The piston then proceeds to complete its upward stroke. At the same time the compression is regulated in such a manner as to develop the highest possible temperature, which would not, however, reach that of auto-ignition.

A few degrees before the dead center is reached, the valve communicating with the cylinder head is opened and the clearance space placed in communication with the head into which compressed air has been forced before starting the motor. This is done only once in the course of operating an engine. The compressed air at a pressure of about 30 kg. (428 lb. per sq. in.) penetrates with its excessive pressure into the clearance space and suddenly forces the mixture back toward one of the sides of the deflector of the piston, producing a strong mixing effect, this being assisted also by the shape of the top of the piston and the compression chamber. Ignition then takes place spontaneously on account of excessive pressure. The explosion forces back into the head the air which came out of it along with some of the gaseous products of combustion. When at the beginning of the expansion stroke the pressure in the head has become equal to what it was at the beginning of the cycle the communicating valve is closed, the expansion in the cylinder itself continuing. With this arrangement it is not necessary to renew the compressed-air charge in the cylinder head as it renews itself automatically, though after some time the air is replaced by gases of combustion.

It is important to note that this cycle is not really the one on which the Ripert motor works, although it is not impossible. The true cycle of the Ripert motor is one in which steam is introduced into the cylinder. This steam, at a pressure of 30 kg. (428 lb. per sq. in.) or more, is contained in the cylinder head and suddenly forces back the cylinder mixture.

The position of the valve with respect to the deflector at the top of the piston is such that during the mixing period a relative stratification of the two fluids, steam and gas, is maintained. At the end of the period of steam injection one part of the chamber is still filled with steam, while in the other the gases (air and oil vapor) are collected.

The ignition occurs throughout the entire mixture at exactly the predetermined moment, either spontaneously as a result of excessive compression, or in the case of semi-Diesel engines, by sudden forcing of the mixture into a preheated chamber or electrical ignition tube. The combustion takes place throughout the entire charge in the form of an explosion. During this explosion while the pressure in the cylinder becomes greater than the pressure

of the steam introduced into it, the steam flows back into the cylinder-head chamber through the valve as long as it remains open. Eventually a certain amount of gas penetrates into the cylinder head chamber in accordance with the point to which it is desired to limit the maximum pressure of the explosion. In multi-cylinder engines the cylinder heads communicate and form a single boiler which insures the uniformity of pressures resulting from the explosions in each cylinder, notwithstanding the unavoidable variations in fuel feeding.

As soon as the downward movement of the piston reduces the internal pressure the gases from the cylinder-head chamber flow back into the cylinder, passing through the valve which is still open in the opposite direction and along with these gases a certain amount of steam enters the cylinder and stays there. When the pressure falls sufficiently low the valve closes. The expansion and exhaust portions of the cycle do not differ from those in conventional engines. The theoretical calculation of the original cycle is given in the original article.

No data of tests are adduced. Some diagrams are given containing "practical" figures, but it is not stated how they are obtained. (*Bulletin Technique du Bureau Veritas*, vol. 4, no. 10, Oct., 1922, pp. 245–247, 2 figs., *gt*)

High-Compression Gasoline Engines

Internal-Combustion-Engine Characteristics Under High Compression, J. H. Holloway, H. A. Huebotter and G. A. Young, Mem. Am.Soc.M.E. This paper is a report of a series of tests conducted during the summer of 1922 by the authors at the Engineering Experiment Station of Purdue University. The work consisted of research into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation. The compression ratio of the engine was 6.75 and the compression pressure 122 lb. per sq. in. gage. The ingoing charge was passed through a hot-spot vaporizer and thence through a cooler between the carburetor and the valves. Jacket-water temperatures between 150 and 170 deg. fahr. were carried at the outlet port of the jacket.

The theory held by the authors as to the causes of detonation of combustible charge is presented briefly. The source of the two phases of detonation encountered in this work is believed to be overheated areas in the combustion chamber. The methods of combating these hot spots are given in detail, and the special equipment applied to the engine to accomplish the desired result is described. The effects of load, speed, compression ratio and mixture ratio are studied, and curves showing the variation in the engine characteristics due to each factor are submitted. All tests were run without a trace of detonation.

From these tests, which are represented as covering only a narrow range in the field of gasoline-engine operation, the following conclusions are drawn:

1 Under laboratory conditions a compression pressure of 120 lb. per sq. in. gage is perfectly feasible when the engine is designed with a full regard for the elimination of the factors that induce detonation.

2 Under service conditions the same attention to these factors will permit the use of much higher pressures than those common at present.

3 An increase in the compression ratio results in a marked improvement in the thermal efficiency and the general performance of the engine at all loads and in the maximum power at all speeds.

4 The sources of detonation are the spark plug, the exhaust valve, the piston head, and any other portions of the combustion-chamber walls that become overheated.

5 The maximum economy is obtained with the leanest fuel-air mixture giving reliable combustion. Such a mixture varies from 0.060 lb. of fuel per lb. of dry air at 25 per cent load, to 0.057 lb. at 75 per cent load; or, from 16.6 to 17.5 lb. of dry air per lb. of fuel. Hence, for this range of load the leanest possible mixture is desirable, provided good vaporization is secured. At a full throttle opening the maximum power is usually sought at the expanse of economy. An 0.075 mixture, or 13.3 lb. of air per lb. of fuel, is rich enough to insure the greatest output.

6 The water-jacket heat loss reaches its maximum value at approximately the mixture giving the highest power with a fixed throttle opening, or a 0.075 ratio.

7 Exhaust temperature is highest with a 0.065 ratio.

8 The power of an engine can be increased 25 per cent by a change in the compression ratio from 4.45 to 6.75, provided detonation is absent.

9 With the same change in the compression ratio the thermal efficiency is raised 7 to 12 per cent through a load range of 25 to100 per cent of the engine power.

10 At full load a mixture temperature of 125 deg. fahr. at the hot spot is high enough to give good distribution in a four-cylinder engine with a properly designed hot spot. If the mixture is cooled below this temperature between the hot spot and the valves, the performance of the engine is improved. A low limit of 100 deg. fahr. at the valves can be allowed safely.

11 At partial throttle opening, a hot-spot temperature of 175 deg. fahr. is not excessive and assists in the use of very lean mixtures for high economy. (*Journal of the Society of Automotive Engineers*, vol. 12, no. 1, Jan., 1923, pp. 111–117, 11 figs., *e*)

Hammer-Spray Injection System. Details of a device for enabling gasoline engines to use kerosene and light fuel oils such as oil of about 34 and 36 deg. B. (Development of the Hasbrouck patents.)

The system consists of a spray of fuel injected into the combustion chamber of each cylinder of the engine by a pump by means of a sudden blow of a hammer on the plunger of the pump. The fuel is injected into the cylinder through a spray nozzle to which flexible tubing is led from a pump; the plunger of this pump is actuated at the proper moment for injection of fuel by a hammer operated by a spring under moderate tension and by a trip cam mounted on a shaft driven by means of a belt, chain or the like.

It is said that when the plunger of the pump is driven down by the blow of the hammer the correct amount of fuel is forced through the tubing past a ball check and injected in a very finely pulverized spray between the seat of the valve and the spherical surface of the valve head against the tension of the spring. One pump plunger and one spray nozzle are required for each cylinder.

Tests of this device have been made by Prof. E. H. Lockwood, Mem. A.S.M.E., of Mason Laboratory of Sheffield Scientific School, Yale University, and two installations have been in service on boats at New Haven for many months. Of the tests made, one was in connection with a single-cylinder four-cycle stationary engine of $4^5/_8$ in. bore and 5 in. stroke, which operated on 36-deg. B. oil and with 25 lb. cylinder compression, starting cold with relieved compression on the second turn of the flywheel after standing idle for over six months. This engine also operated on alcohol and kerosene with this device installed. A single-cylinder two-cycle marine engine of similar bore and stroke was tested by Professor Lockwood, and is now driving a 23-ft. by 9 ft. 6-in. converted catboat about $5^1/_2$ m.p.h. This engine starts cold directly on kerosene or fuel oil on 35 lb. compression, and the consumption is moderate, one gallon sufficing for two hours and twenty minutes' running. (*Motorship*, vol. 8, no. 2, Feb., 1923, p. 118, 3 figs., *d*)

MACHINE PARTS AND DESIGN

Belt Transmission, D. Genkin. An extensive, largely mathematical analysis of belt transmission. As a rule, in computing the efficiency of belt transmissions only losses on pulleys are considered. In the present instance the author, after reviewing the known formulas, endeavors to determine the magnitude of all the other losses. Among other things, he calls attention to the undesirability of using belts in power transmission from an electric motor.

The conclusions at which he arrives are that no matter how carefully belt transmission may be designed and worked out, the power losses inherent in this type of transmission can rarely be brought below the five per cent level. As regards less carefully designed belt transmissions, the losses involved therein may not only be in excess of all reasonable limits but may cause a rapid wear of the bearings and frequent stoppages of work due to the wear on the belt itself.

The article itself, after a brief introduction, proceeds to a mathematical study of the operation of a belt transmission, which, among other things, investigates the relation between the initial tensions on the tight and loose sides of the belt, the variation of tension

along the portion of the belt in contact with the rim of the pulley, the effect of elongation of the belt in running, and the calculation of the suction of the belt.

The selection of the best tension in the belt is discussed, after which an extensive abstract is quoted from Taylor's work on Shop Management.

The losses due to periodic elongation and contraction of the belt are mathematically discussed, likewise the losses due to the resistance of the belt bending around the pulley. (*Revue Générale de L'Electricite*, vol. 12, no. 25, Dec. 23, 1922, pp. 975–988, 5 figs., *mtA*)

MACHINE TOOLS

Pull or Push Cutting Strokes, F. H. B. One of the problems in the use of certain types of machine tools is whether the cut shall be taken on the pulling or the pushing stroke. This consideration applies to such machines as possess holders or rams carrying the tool out from the end. In such a category come shapers, broaching, keyway-cutting and filing machines, hacksaws and some of the gear shapers. The primal difference in cutting on the pull or the push stroke is that of change from tension to compression, a change which may affect all the elements: the tool, the ram, its slides and the means of propulsion. In discussing the advantages or disadvantages of either method the author cites the ordinary pillar shaper where the presumed advantage of the pulling stroke, namely, consolidating the slides of the table and saddle by the cutting pressure, is discounted by the fact that substantial table supports are now employed in most of the ordinary shapers to withstand the downward and outward thrusts.

The author discusses in detail keyseating machines, broaches, hacksaws and gear shapers. In keyseaters a draw cut may be usefully employed if long hubs require it for keyways cut in their bores.

In case of gear shapers both the push stroke and the draw stroke may be used, the latter being employed in the Fellows shaper which possesses a vertical ram. There are, however, shapes that cannot be cut on the pulling stroke, for example, gear clusters, where owing to the contiguity of another tooth ring, the cutter cannot start up from below. However, the design of the spindle end of the Fellows machine permits of fixing on the cutters for either the push or the pull stroke without trouble. (*Mechanical World*, vol. 73, no. 1879, Jan. 5, 1923, pp. 2–3, 3 figs., *p*)

MARINE ENGINEERING (See Special Processes)

MEASUREMENTS

Passing of the Quarter. On January 1, 1923, by an amendment to the Corn Sales Act the hundredweight has become the sole legal standard for sales of dry products in Great Britain and Ulster, thus eliminating the quarter as the legal measure.

The bushel or small box was the ancient unit of Saxon dry measure. The quarter was eight bushels and the system was to buy by measure, quality being roughly appraised by weight. For more than a century, however, there has been a tendency on the part of buyers to insist on sales by uniform weight, in addition to which the measure "quarter" was uniform throughout the country. (*The Times Trade and Engineering Supplement*, vol. 11, no. 237, Jan. 20, 1923, p. 429, *g*)

METALLURGY (See Engineering Materials)

MOTOR-CAR ENGINEERING

Alcohol as Fuel. One of the main difficulties in the use of alcohol in engines is that of starting. This has, however, been solved by the so-called bi-fuel scheme in which starting is done on gasoline and running on alcohol.

In this connection, the original article describes the gasoline-alcohol Claudel-Hobson carburetor and the so-called Hobson non-pinker, a device to prevent "pinking" (detonation knock) in high-compression engines, of importance because with alcohol the higher compression is needed than with gasoline.

The device consists of a diaphragm-control needle valve in a small auxiliary carburetor so connected to the main carburetor that at periods when the depression in the main carburetor is low the device comes into operation and allows alcohol to feed to the cylinders. The depression is low when the throttle is open and high when it is closed. Therefore the alcohol is fed to the cylinders and cut off again exactly at the required moment. (*The Autocar*, vol. 49, no. 1419, Dec. 29, 1922, pp. 1310–1311, 2 figs., *dg*)

A Six-Wheel Motor Omnibus

Six-Wheel Motor Omnibus in Paris. Description of a new type of motor omnibus being placed in operation in Paris. One of the obstacles in the way of more efficient utilization of motor omnibuses is their limited seating capacity. Thus, while the ordinary trolley car can carry up to 100 passengers and more in rush hours, a motor omnibus in Paris has only 38 seats. To increase the seating capacity, seats would have to be provided on top, an arrangement which has not proved popular in Paris although extentensively used elsewhere, as, for example, in England. One way to meet this situation was to increase the overall wheelbase by

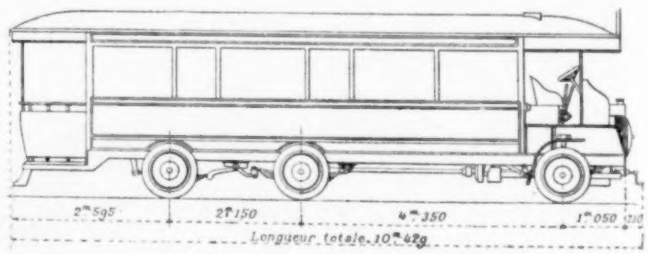


Fig. 3 Six-Wheel Motor Omnibus in Paris
(*Longueur totale* = total length.

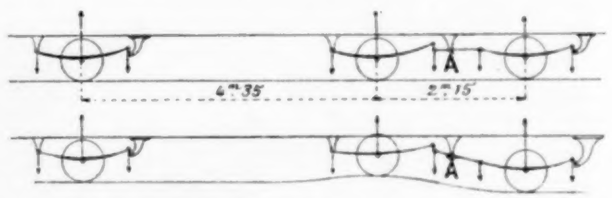


Fig. 4 Balanced Suspension Arrangement of the Paris Six-Wheel Motor Bus

providing an intermediary axle, which meant a six-wheel arrangement and raising the seating capacity to 48 seats. Fifty such buses are already under construction.

The new bus has a total length of 10.43 m. (34.4 ft.) and a width of 2.25 m. (7.25 ft.). The axles are spaced unequally, the front axle being 4.35 m. (14.4 ft.) and the rear axle 2.15 m. (6.90 ft.) from the middle axle, the total wheel base being therefore 6.50 m. (21.30 ft.). The steering is on the front and rear axles only. All the wheels have the same diameter 0.95 m. (37.4 in.). The front and rear set are equipped with single solid tires, the middle wheels with double tires of the same section.

The chassis is equipped with a special device for maintaining constant the distribution of load on the wheels. In a vehicle carried on two axles this distribution does not change materially notwithstanding variations in level of the road, but this would not be the case in a vehicle carried on six wheels, unless special means were taken to accomplish it (in this case a balancing gear joining the extreme tips of the rear and middle springs). This balancer *A* (Fig. 4) oscillates about a shaft carried in a support rigidly held on the chassis. This being so, the system of forces acting on the chassis is of a statically determinate nature and the reactions on the wheels are independent of the relative position of the latter. The loads on the steerable wheels may be equalized by suitably locating the middle axle, which is also very useful from the point of view of stabilization of direction. Another advantage of a balanced suspension is that it decreases the vertical movements of the carriage, which reduces the jarring and the wear both on the omnibus and the road.

The vehicle is provided with a mechanism brake, a wheel brake and an auxiliary braking device acting on the middle wheels and operable from the rear platform.

The omnibus (Fig. 3) has an interesting steering system which cannot be described here on account of lack of space. It is pointed out in this article, however, that a six-wheel car has less tendency to skidding than one running on four wheels. (*Le Génie Civil*, vol. 81, no. 27, Dec. 30, 1922, pp. 605–607, 11 figs., *d*)

Aster Engine Valve Gear

THE "EIGHTEEN SIX" ASTER. Description of the Aster automobile, built by a British company which for 22 years has manufactured engines for automobiles.

One of the interesting features of this engine is its valve-operating gear (Fig. 5). The valves are directly overhead and in line. They are operated by rocker levers, the ends of which are pushed up by push rods from the tappet gear above the camshaft. The latter is silent-chain driven and is located in the crankcase. The two features of this gear are the absence of working bearings in the rockers and the provision of silent oil cushioning to the tappets and push-rod gears.

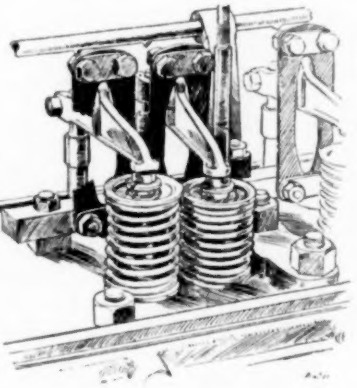


FIG. 5 VALVE-OPERATING GEAR OF THE ASTER ENGINE

The rockers instead of being pivotally mounted on trunnion bearings as is the conventional practice, are rigidly bolted to upstanding steel spring pillars which curve to allow the outer ends of the levers to depress the valves. The push rods are provided with ground spherical seatings, carefully constructed so that there will always be a film of oil between the opposed surfaces. This is said to insure silence. The measure of the accuracy of the fit here is important, and the spherical surfaces are very carefully machined and ground in order that an oil film shall always be present between them.

The fan is provided with a telescopic adjustment for height in order to allow of the adjustment of the belt. The adjustment is fixed by a small hand lever and can be made without the use of tools.

One of the minor features is that the water outlet pipe from the cylinder head to the top of the radiator is stayed by a couple of stay rods at the side, which have the effect of staying the radiator to the engine. Another point about the engine design is the use of a small air pump driven by a cam on the camshaft and providing air pressure for the rear-tank fuel supply to the carburetor. This pump is fitted with a release valve which is in an accessible position, is easily adjustable from the outside, and may be readily dismantled should occasion arise for any adjustment or examination.

The transmission of the power from the gear is carried out by means of an enclosed propeller shaft which runs in a long tapered torque tube forming the forward extension of the live axle The function of this tube is to take the torque and the propulsion loads. (*The Auto-Motor Journal*, vol. 28, no. 2/1149, Jan. 11, 1923, pp. 27–30, 11 figs., *d*)

POWER-PLANT ENGINEERING (See also Special Processes)

THE DESIGN OF STRUCTURAL SUPPORTS FOR TURBO-GENERATORS, Edward H. Cameron. Discussion of the relative merits of the three common types of pedestals for turbo-generators, namely, reinforced concrete, structural steel, and composite. The author believes that the tendency of the steel pedestal to vibrate with the machine constitutes its one disadvantage when compared with the concrete pedestal, and the design of a steel pedestal so proportioned as to avoid this vibration is a difficult problem.

The pedestal must have mass enough to absorb all vibrations and be rigid enough to prevent swaying. The most practical means of arriving at the requisite mass for a turbo-generator pedestal is by a study of existing designs in satisfactory operation both as to total mass and its distribution. To facilitate this the author gives weight-ratio curves and cost curves.

The original article gives a series of practical suggestions as to the best method of proceeding in designing pedestals for turbo-generators, the general advice being that utility or fitness rather than relative cost should be made the sole basis of comparison in deciding on the type of pedestal to adopt for a turbo-generator installation. As regards costs it is stated that for ordinary designs the cost of the pedestal should not exceed about 5 per cent that of the turbo-generator, and that in general any saving of one particular type of pedestal over another should not be more than about 1 per cent of the cost of the unit which it supports. Each type of pedestal has its field. For the smaller units it is believed that more concrete pedestals are in use, whereas the reverse is probably true of the larger units. The composite type, combining the advantages of both concrete and structural steel, is coming to be more and more favored for all sizes of turbo-generator units. (Paper before the Monthly Meeting, Dec. 20, 1922, of the *American Society of Civil Engineers*, abstracted from advance publication, 16, pp., 6 figs., *p*)

Increase of Economy by Changes in Boiler Design

PRINCIPLES OF BOILER DESIGN, C. E. Stromeyer. Discussion of some features of boiler design, with particular reference to attempts to increase economy.

In view of the injury done to boiler parts and to brickwork if the furnace temperature is high, as it must be with perfect combustion, the author suggested some years ago the resort to double combustion. The fuel in the furnace would be burned not to carbon dioxide but to monoxide. The resultant temperature could then not exceed about 2500 deg. fahr. and the temperature curve in the boiler would run in a manner entirely different from that of today. This arrangement would present difficulties when using customary types of boilers and the present types are merely to be modified. There would be difficulties from the increase of furnace temperature and, in particular, from enormous heat radiations, which brings up the question as to whether heating surfaces can be screened from the radiation of the incandescent fuel.

Assuming that the radiant heat of the furnace has been disposed of one way or another, we are face to face with the question of convection. Let there be two fluids of different densities on both sides of a plate—heating surface—then, neglecting the very slight resistance offered by the plate to the passage through it of a certain quantity of heat H per hour, it appears that—

$$H = C\,(T_1 - T_0)\,D_1\,(1 + 0.02\,V_1) = c\,(T_0 - T_2)\,D_2\,(1 + 0.02V_2).$$

Here C is a constant which is, however, not quite the same for all gases and fluids. T stands for the various temperatures, T_0 being that of the plate, D stands for densities and V for velocities in feet per second. The two right-hand expressions determine the ratio of the subdivision of the available temperature difference $T_1 - T_2$. The ratio is $(T_1 - T_0)/(T_0 - T_2) = (D_2/D_1)\ (1 + 0.02\ V_2)/(1 + 0.02\ V_1)$. Let the one fluid be water, whose density is about 800 times as great as that of air, then for small values of V the ratio of the excess temperature of the air over the plate, $T_1 - T_0$, would have to be about 800 times the excess temperature of the plate over that of the water $T_0 - T_2$. To increase V_2 would only increase this disproportion, but this would be diminished, and the heat transmission per square foot of heating surface increased, if the air velocity V_1 were increased. Our efforts should therefore be centered on increasing the velocities of gases and steam and not on increasing the water velocity, except, of course, for circulating purposes and for liberating the steam as it is generated.

It could easily be shown that a minimum heating surface will be obtained if the temperature ratio $(T_1 - T_0)/(T_0 - T_1)$ is near unity. This is of importance as regards superheaters.

The problem of creation of the draft velocities is discussed and the author shows that the cost of a draft produced without a chimney and with gases cooled down to the surrounding temperature with the fan will be very much lower than when produced by natural draft in terms of coal used. Nevertheless, fans do not replace chimneys, because with present-day boilers the temperature of the waste gases cannot be reduced much below 400 deg. fahr., and because chimneys are necessary anyway to carry the gases above the housetops.

From this the author proceeds to a discussion of the employment of air heaters as a possible means of waste-gas cooling and shows the many difficulties involved in their design.

He considers the superheater a necessary adjunct of modern engines and makes an estimate of the relative velocities, using however, relative densities instead of temperatures in the calculations. The steam velocities, he says, should be less than those of the gases, but both should be high. The loss of power in the main engine, due to drop of steam pressure in the superheater, should be estimated, also the increased friction in the steam pipe due to increased volume, or increased radiation, due to the adoption of slightly larger diameters. The simplest way out of this complication would probably be to start with the pressure required at the engine, and to make the boiler strong enough to bear the few additions. The problem is then reduced to the simple one of taking into account the increased cost of the boiler due to the small increase of pressure. Steam users should not expect to gain in both directions. If by employing high velocities the superheater surface has been reduced, a loss of steam pressure must result. But steam users would have cause to complain if only one of the velocities were kept high, for then there would be friction losses with only one-half the possible gain.

The interesting problem has now to be solved as to where the superheater should be placed. It certainly cannot be placed next to the air heater, because here the temperatures are too low. The further we move away from the air heater, the hotter will be the waste-gas temperature, the better the heat transmission, the smaller the heating surface required, and the lower, if desired, can the velocity of steam and gas be fixed. The cost of each alternative would have to be worked out.

This is followed by a discussion of economizers, high velocity of flames (based on the experiments of Professor Nicolson), reductions of furnace temperatures and oil burning. (From a Report to the Manchester Steam Users' Association, 1922, abstracted through *The Engineer*, vol. 134, no. 3495, Dec. 22, 1922, pp. 672–673, *gt*. Compare editorial, dealing with other parts of the same report in the same issue of *The Engineer*, p. 669)

Steam Velocity. In an editorial a question is asked as to whether we should guess or know what the maximum steam velocity in a steam pipe should be, and whether it should be 6000 ft. per min. or 20,000. If 6000 is used where 20,000 would give entirely satisfactory results, a lot of money is wasted. On the other hand, if excessively high velocities are used, trouble is certain.

Most of our formulas for the flow of steam through piping and fittings were inherited from the era of low pressures and saturated steam, and it is the opinion of many practical designers that they are totally inadequate for the conditions found in large stations. Moreover, it appears that the laying out of steam pipes on a velocity basis is satisfactory only where a wide range of velocities is used to fit various conditions.

In this connection, considerable interest attaches to the recent statement of John H. Lawrence, Mem. Am.Soc.M.E.—who has had extensive experience in power-station design—that the proper steam velocities for the conditions found in large modern power stations may be roughly approximated by allowing 1000 ft. per min. velocity for each inch of pipe diameter. If this rule is approximately correct, it is seen that 6000 ft. per sec., while about right for a 6-in. pipe, is far too low for a 20-in. pipe. This rule of thumb was not proposed by Mr. Lawrence as a hard-and-fast law of good practice, but merely as something tangible in the field between pure guesswork on the one hand and incorrect formulas on the other. In reference to the latter Mr. Lawrence said that actual measurements at the Hell Gate Station showed pressure drops far lower than those figured by any of the standard formulas for steam flow. As to losses through fittings and valves, the condition of knowledge is, he said, even more chaotic.

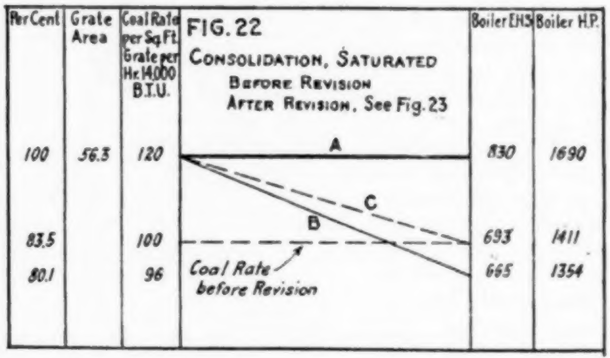
The writer expresses the hope that The American Society of Mechanical Engineers will follow the suggestions of those members who are fully alive to the importance of this problem, and believes that it should certainly be worth while to make an extensive field survey to determine the actual pressure drops obtained with the various fittings, pipe sizes, pressures, superheats and steam velocities found in existing plants. From a careful study of the tabulated data of such a survey it should be possible to develop formulas suitable to the need of the practical designer. (Editorial in *Power*, vol. 57, no. 3, Jan. 16, 1923, pp. 105–6, *p*)

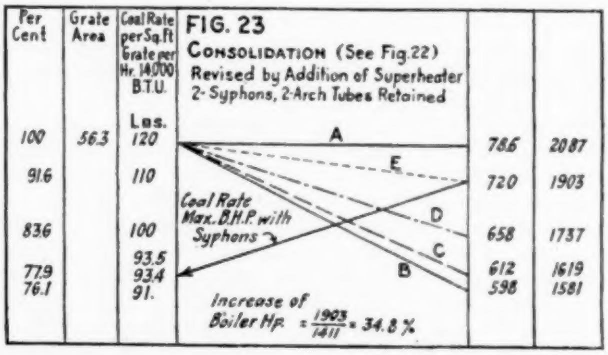
RAILROAD ENGINEERING

Graphical Analysis of Locomotive Boiler Proportions

Graphical Analysis of Locomotive Boiler Proportions, C. A. Seley. A graphical analysis of locomotive boiler proportions developed with particular reference to the design of locomotives equipped with the so-called thermic siphon (For description of the thermic siphon, see Mechanical Engineering, March, 1919, p. 284). It is based on the engineering methods and data proposed by F. J. Cole in designing boilers on horsepower basis.

The article is not generally suitable for abstracting, but some of the conclusions arrived at may be reported here. One of the figures (No. 16) illustrates the results of insufficient grate surface, which means high coal-burning rates and loss of economy and efficiency. It has been stated that a 120-lb. coal rate is about the maximum amount for economical evaporation, yet this diagram shows 134 lb., a very high rate for continued heavy service. The United States





Figs. 6 and 7 Diagrams of Consolidation Locomotive Before and After Revision

(The figure numbers above refer to the illustrations as placed in the original article.)

Railroad Administration 2-6-6-2 design is in a similar class, with high coal rate for heavy service.

A claim is made in the article that some of the deficiencies of present-day locomotives may be compensated for by the addition of a thermic siphon. By way of illustration of these claims the following may be cited:

An increase of tonnage rating of 20 per cent sounds big, but is actually being accomplished in the revision of a series of Consolidation locomotives originally heavily built and capable of such increase in tractive effort by cylinder and steam-pressure changes. The original boiler had four arch tubes but no superheater and was of 1411 boiler hp. The boiler revision consisted of superheating, adding two siphons, retaining two arch tubes, the combined effect being to give an equivalent equated heating surface of 720 sq. ft. or 1903 boiler hp., an increase of 35 per cent, with a very moderate coal rate, all as shown in Fig. 6.

Fig. 7 shows distribution in percentage of the heating surfaces and the effect of the revised design, as compared with the original dimensions equated to superheat ratio for comparison, or 74.14 per cent. The revised locomotive has successfully handled an increase of 20 per cent and over of the original engine tonnage rating, and, while this is an exceptional case, due to some of the features involved, no doubt, there are many locomotives that are

capable of a similar line of treatment. (*Railway and Locomotive Engineering*, vol. 36, no. 1, Jan., 1923, pp. 9–13, 24 figs., *cg*)

European All-Steel Sleeping Cars

European All-Steel Sleeping Car, Wm. Redpath. Description of what is said to be the latest word in Continental sleeping-car construction. These are not only the first all-steel sleeping cars built abroad, but the first European cars in which steel castings have been extensively employed to strengthen and simplify underframe and truck construction.

The whole of the structure of the body is of steel, the sides being constructed with 1/8-in. pressed-steel members of varying sections connected longitudinally to rolled-section angles at the base which rest on the underframes. At the top the vertical members are connected by the two angle rails. The sides below the waist are sheeted with 1/8-in. steel sheets of a special quality which give a superior finish. The sheeting above the waist is pressed in 1/8-in. plate to form the window openings, as many as four windows being pressed in one piece. Steel moldings are used to cover the butt joints of the body side plates, the whole side being riveted together with rivets countersunk on the outside to give a clean appearance to the outside of the coach. The sides thus become deep girders capable of supporting the whole of the superstructure.

The roof is elliptical, being constructed of a rolled-section angle carline riveted to upper partition plates. These latter extend down to the cantrail level across compartments and are shaped to suit the ceiling at the corridor. The roof is designed to allow of the water tanks being assembled or removed through the outside sheeting, covers with suitable joints being provided.

The structure of the body is entirely of steel, being built in jigs in units: full-length compartment side, full-length corridor side, full-length roof, body ends, platform ends and canopies, thus insuring complete interchangeability as well as ease of production. These units, which for the most part consist of pressings and rolled sections all machined to templets, are quickly assembled whole on the underframe, leaving the shell ready for the assembling of interior finish. To insure absence of vibration and drumming, the steelwork has been covered on the inside with canvas and insulation from heat, and cold has been well provided for. Free air circulation between the outer skin and inner finish is also arranged for the prevention of condensation.

These cars are arranged essentially in a different manner from sleeping cars in America. They have been designed to carry sixteen passengers, the arrangement being eight single compartments, four double compartments, and two lavatories, six of the single compartments being provided with communicating doors capable of being locked from either side. The seats of each compartment turn over to form the bed, the bedding being secured to the undersides of the seats in dustproof envelopes. The seat back of the double compartment is arranged to lift to a horizontal position to form an upper berth, being supported by pull-out brackets fixed to the body side and corridor partition; safety straps supported from the ceiling are also provided.

There are other facilities not available in American sleeping cars. Thus, incorporated with the vestibule ends are cupboards for ice and wine, utensils and coal, with linen cupboards in the ceiling. The cool wine cupboards are insulated with asbestos and are zinc-lined.

There are two heating systems: one, the usual through steam heating, and the other by hot-water circulation. For the latter a heating chamber is provided at one end of the corridor at which is fixed a coal-fired boiler; circulating pipes of copper are run from boiler to a hot-water tank in the roof, and from this around both sides of the car.

As the cars run over many railway systems, some of which use vacuum and others compressed air, it has been necessary to arrange the brake rigging for use with either system. When the vehicles are in use for the vacuum system, two 24-in.-diameter cylinders operate a pair of brake shafts from which the power is transmitted to the brake blocks by suitable rigging, and when the Westinghouse system is in use, the power is obtained from a 17-in. diameter cylinder. Further, the vacuum brake is fitted with a converter cock for use on certain sections. The Westinghouse brake is fitted with a double pipe line so that the system may be either automatic or controlled. The same brake rigging can be operated by hand from a wheel placed in the vestibule at one end of each car.

The cars were built at the Leeds Forge Company in England and their transportation to the coast and shipping them to France presented a difficult problem. It was, however, arranged to have the cars travel to the port of shipment on their own wheels complete, excepting for the removal of a few parts of minor importance. There it was found that the Channel ferry steamers built during the war for the purpose of carrying rolling stock to the Continent were available.

It was found necessary, however, to construct the new terminal at Immingham, where these cars could be loaded on to the boats. The problem of loading was not an easy one either and, for example, ramps were provided over which the cars were run on to the ferry-boat deck direct from the quay, an ingenious arrangement having been installed to allow for the rise and fall in the dock water level to prevent delay in loading owing to tidal conditions. (*Railway Review*, vol. 72, no. 1, Jan. 6, 1923, pp. 63–67, 8 figs., *d*)

REFRIGERATION (See also Special Machinery)

Comparative Ammonia Condenser Reports, P. Wilson Evans. For a number of years Armour & Co. have compiled a weekly comparative statement showing data on ammonia condensing for their principal plants. By means of these reports it has been possible to deduct and remedy inefficient operating conditions with a resulting saving in power and operating expense. A copy of one such report is given in the article here abstracted.

One of the columns of this report shows a total excess pressure over ideal conditions. It is the endeavor to hold this total excess pressure down to not over 25 lb., but it is difficult to accomplish this. It is only by keeping constantly after this phase of operation that this excess pressure is kept from going considerably higher. The red pencil marks on the copies of the reports sent to the different plants indicate whether the condenser should be purged or other steps taken to reduce the pressure.

In case a plant is found to be materially out of line in its condenser pressure the question always arises as to how much of a loss in dollars and cents this condition is causing. Cases have arisen where the total excess pressure has been as great as 80 lb.

The original article presents a chart showing the horsepower required to compress adiabatically the ammonia required to produce one ton of refrigeration, assuming the suction gas dry and saturated. The curves of the chart were calculated by the author and are plotted with horsepowers per ton as ordinates and absolute suction pressures in pounds per square inch as abscissas.

From an analysis of the figures as reported in one of the weekly comparisons it would appear that in many cases purging of the condenser is necessary to reduce the excess pressure present, and the author shows how materially a reduction of excess pressure affects the cost of operation.

While there is a well-grounded prejudice against too much condenser purging on account of the possibility of excessive ammonia loss, actually the amount of this loss depends largely upon the care taken in purging. In the author's opinion the most satisfactory method of purging an ammonia compressor is to shut it down and allow water to flow over it until there is no material difference between the temperature of the water going on and coming off. Then observe this water temperature and find from the ammonia table the corresponding condenser pressure. This pressure represents accurately the vapor pressure of the liquid ammonia in the condenser and if the gage on the condenser shows higher pressure, the excess is due to non-condensable gases such as air. The purging should be discontinued at a point somewhat above the pressure corresponding to the water temperature, thus assuring that there will be no great amount of boiling off of liquid ammonia.

The difficulty in purging below the pressure corresponding to that of the ammonia vapor at a specific temperature is to know just when to discontinue it, but this is due to excessive pressure of non-condensable gases assumed in this case. Under more normal conditions it is satisfactory to discontinue the purging just at or slightly above the ammonia vapor pressure corresponding to the temperature of the water flowing over the condenser. If this is done, the loss of ammonia at all times will be insignificant. Or-

dinarily, it is considered better practice to purge several times in this manner than to continue the purging to a lower pressure. (*Power*, vol. 57, no. 1, Jan. 2, 1923, pp. 28–30, 1 fig., *dp*)

RESEARCH (See Engineering Materials)

SPECIAL MACHINERY

Vapor Recompression System for Evaporators. Discussion of regenerative evaporation, with comparison of operative economies with single and multiple-effect evaporators. A bibliography of patents and literature is appended.

The nozzle systems are considered to be the easiest to discuss qualitatively. For high efficiency it is necessary to work with a small temperature drop and very high-pressure steam. To get double-effect efficiency (1 lb. of vapor entrained per pound high-pressure steam), the total temperature drop may not be over 18 deg. fahr. for 100-lb. steam, 22 deg. fahr. for 150-lb. steam, or 22.5 deg. fahr. for 175-lb. steam. Ordinarily evaporators are designed to operate with from 5- to 15-lb. steam. If a single-effect evaporator with a nozzle compressor be compared with a double working between 10 lb. and 26 in. vacuum, it will be found that the double has a total available temperature drop of 100 deg. fahr. against, say, 20 deg. for the other. Hence, on material of no elevation in boiling point the double would have five times the capacity of the single, twice the heating surface, and would require the same amount of steam condensing water and accessories.

The comparison used is more strongly in favor of the double when the plant has exhaust steam to spare, as then the double saves either all the high-pressure steam used in the nozzle (if exhaust steam is available, which otherwise would be wasted) or it saves all the condensing equipment and condensing water otherwise needed for the prime movers.

The best use for the nozzle is the plant where all exhaust from prime movers is used in the evaporators and in addition make-up has to be supplied as live steam. A nozzle may be substituted for the usual reducing valve on the make-up steam line; provided, of course, that the evaporator in question is a multiple effect with a small enough temperature drop in the first effect to make the nozzle efficiency appreciable. Here again attention must be paid to the rapidly decreasing efficiency of the nozzle as the steam pressure drops; because if the amount of make-up needed is variable, the nozzle will give useful results only when the throttle valve is wide open. Under conditions demanding less than the maximum amount of make-up steam, its capacity will be negligible.

It has been suggested by Claassen that several small nozzles in parallel be cut in or cut out one at a time as the demand for make-up varies, but each to be either completely closed or wide open and never throttled.

The remainder of the article, though of considerable interest, cannot be abstracted here owing to lack of space. It is devoted to an extensive discussion dealing with the selection of the type of evaporation equipment as affected by the method of power generation at the plant either available or to be installed. A bibliography on vapor-recompression systems for evaporators, and, to some extent, evaporation generally, is appended. (*Chemical and Metallurgical Engineering*, vol. 28, no. 2, January 10, 1923, pp. 73–78, *gcA*)

Oxygen Enrichment of Blast in Blast Furnaces

Oxygen-Enriching, Superheating, and Drying of the Blast. The question of enriching the blast in oxygen is now the subject of an investigation by the U. S. Bureau of Mines. It is of interest to mechanical engineers as the majority of the methods now known to accomplish this purpose involve the use of compressor and low-temperature refrigeration equipment.

In a paper before the Liége Congress M. Derclave, as regards enriching the blast in oxygen, arrives at the following conclusions: The addition of 5 per cent (in volume) of oxygen does not improve the working of a blast furnace upon the whole, because the advantages gained in respect of coke consumption are lost by the reduced calorific value of the furnace gas. Any further increase in the oxygen content would have no effect, because the limit of the indirect reducing power of the gas has almost been reached, the ideal limit, according to Gruner, being reached when $m = 1.21$ is raised to 1.57—that is, when the whole of the oxygen in the burden is abstracted by the CO. This condition is, of course, impossible to attain so long as there is any water vapor in the flowing gas, as must be the case when damp and chemically hydrated ores are used, like minette. The 5 per cent to 6 per cent in volume of oxygen added must be considered the limit beyond which the point of equilibrium is approached, at which the quantity of CO required at the tuyeres for fusing the materials is equal to that necessary for the complete reduction of the charge by the gas. Beyond this point no further increase in efficiency can be realized in blast-furnace working. One has reached the most favorable conditions for the indirect reduction by CO, which is the essence of successful blast-furnace working, as shown by the equation:

$$Fe_2O_3 + 6\,CO = 2\,Fe + 3\,CO_2 + 3\,CO \qquad [1]$$

for which the ratio CO_2 to CO in volume equals unity, or 1.57 in weight.

To obtain further economy in fuel consumption it would be necessary to oxidize the carbon directly by the oxygen in the ore, and to find some other apparatus than the furnace which would realize the reaction represented by the equation:

$$Fe_2O_3 + 2\,C = 2\,Fe + CO_2 + CO \qquad [2]$$

which shows that carbon utilized in this direct way would give a reduction three times greater than when burned at the tuyeres of a furnace by the air in the form of CO. Because, according to Equation [2], to reduce two units of iron, two units of carbon are required in the case of direct reduction, while by Equation [1], on the contrary, six units of carbon are required in the case of indirect reduction.

It is easy to calculate that to obtain 1000 kg. of iron containing 3.5 per cent C, by the indirect method, 35 kg. of C are required to carbonize the pig iron, a further 515 kg. to reduce the iron oxides indirectly, and 25 kg. for the direct reduction of the other oxides; thus a total of 575 kg. would be required for the fusion of the iron and the slag and the consequent separation of the metal from the gangue.

By direct reduction no more than 192 kg. of carbon would be required, but it would be necessary to draw upon other sources of heat to insure fusion. By utilizing methods of heating not entailing the combustion of carbon, such, for example, as heating, drying, or enriching the blast in oxygen or electrical heating, the whole of the carbon would be utilized for the reduction of the ores and not for smelting, and the saving in fuel would thus be pushed to its maximum.

There is, then, a comparatively narrow limit to the extent to which oxygen can be added to the blast. Even with the addition of 5 per cent in volume, that is 27 per cent of oxygen by weight, the limit is reached; for the high temperature reached at the base of the furnace would destroy the lining, while at the top of the furnace there would be a rapid falling off in the reducing effect of the gas. As regards the hot blast, it, among other things, increases the ratio of CO_2 to CO in the furnace gas; that is, the ideal operation is more closely approached. The hotter the blast, the smaller will be the quantity of carbon consumed at the tuyeres, and consequently the volume of CO produced in that region will be reduced. Since the oxygen content of the ore remains the same, the proportion of CO_2 will increase and the ideal ratio of CO_2 to $CO = 1$ (in volume) will be attained. The excess of CO_2 in the reduction zone will then act on the soil carbon, and, while the consumption of fuel is reduced in the region of the tuyeres, it is increased in the reduction zone. The final result will be that there will be a notable reduction in fuel consumption without affecting the quality of the product. (Paper before the Liége Congress. Abstracted through *The Iron and Coal Trades Review*, vol. 106, no. 2863, Jan. 12, 1923, p. 53, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Internal-Combustion Engines

Preliminary Draft of Another Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

THE Power Test Codes Committee on Internal-Combustion Engines which developed this Code is headed by Dr. Charles E. Lucke as Chairman, the other members being Edward T. Adams, Harte Cooke, Max Rotter, and Arthur West.

The Committee and the Society will welcome suggestions for corrections to and modifications of this draft of its Code from those who are especially interested in the testing of Internal-Combustion Engines. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

Tests for determining the performance of internal-combustion engines by this code apply to all forms of internal combustion engines, but are limited to the engines alone. Separately driven auxiliaries that are essential to the operation of the engine, such as scavenging pumps or blowers and injection air compressors, for example, must be included in the tests, but the testing of such units must follow the other codes appropriate to the unit to be tested and the results in horsepower absorbed introduced and used in this code.

2 Internal-combustion engines, compared to others for which codes are available, include a much greater variety in form, size, speed, weight, fuels and other operating conditions, with more or less special features for particular applications. This fact makes it necessary in a single inclusive code like this to leave many details of the test to the judgment of the test engineer, or to be made the subject of expressed agreement before the test is started. Suggestions are offered in this code as to limitations, alternatives and difficulties to aid in making selections of details, always with the understanding that suitability to the case shall be the basis of judgment.

3 Sizes of internal-combustion engines coming within this code range from one horsepower to several thousand. Speeds range from less than 100 r.p.m. to over 3000 r.p.m. Numbers of cylinders range from one to twelve or more; some horizontal and others vertical; some single-acting and others double-acting; some two-cycle and others four-cycle, with every variety of attached and separate scavenging pump for two-cycle engines. Fuels range from the lightest distillates to the heavy residue fuel oils, organic and mineral in the liquid-fuel class, and in the gaseous form include every combustible gas commercially available. Purpose and variety of load or other service conditions normal to and proper for each engine cover equally wide ranges. Stationary engines operate at all loads normally at constant speed under governor control, for any period of time and any degree of intermittence of use. Marine engines operate normally at full load, and the constant speed fixed by the propeller, but must be maneuvered ahead and astern at any speed under hand control, and may operate for any period of time from short intermittent runs to the continuous full load for a month or more required of seagoing motorships. Aircraft engines must meet about the same service conditions as marine engines, except that a smaller length of single run is required, but they must operate in the greatest known ranges of atmospheric pressure and of temperature. Other engines of the automotive group, those for land transportation, including those for automobiles, motor trucks, tractors, railroad locomotives and self-contained cars, are essentially variable in speed as normally used, and equally variable in torque, horsepower being as much a matter of secondary importance as in a hoisting engine or steam locomotive. The engines of this last group drive their vehicles through gear sets of different speed ratios, at changing vehicle speeds and changing vehicle resistance, and tests of them must be conducted with due regard to these service conditions.

It is obviously impossible in any single code to prescribe tests in detail that could be equally applicable to all these conditions, so that some exclusions are necessary. At the same time it is highly desirable that tests for all internal-combustion engines set by this code should have as much in common as may be possible, even if some latitude of judgment is necessary to make this possible.

4 Excluded from this code are the following:

(a) Complete internal-combustion engine stationary power plants using gaseous or liquid fuels, which have power-generating or power-absorbing auxiliaries separate from the engine
(b) Motor-boat and motorship power plants and the vessels themselves
(c) Aircraft and their power plants
(d) Land propelled vehicles, with or without speed-change gears, including motorcycles, automobiles, motor trucks, tractors and rail locomotives or self-contained cars
(e) All internal-combustion engine "sets," consisting of an internal-combustion engine so combined with a driven unit as to make it impossible to separately determine the performance of the engine itself, or such as falls within the scope of other codes, excepting only electric generating sets. Among these sets herein excluded are internal-combustion-engine pumps, compressors and hoisting outfits, whether used for hoisting or for hauling
(f) All internal-combustion engines, the construction or operating conditions of which prevent an output determination in terms of either brake horsepower or kilowatts, for a generating set.

5 Included within this code are the following internal-combustion engines not excluded by any of the items of Par. 4:

(a) Stationary engines, and electric-generating sets even if not intended for stationary use, burning gaseous or liquid fuels, including the scavenging pumps of two-cycle engines, and injection air compressors, if used and separately driven
(b) Marine engines exclusive of propeller, and burning light or heavy liquid fuels
(c) Aircraft engines limited to block tests, exclusive of propeller, and burning light liquid fuels
(d) Land vehicle engines limited to block tests and burning light and heavy fuels.

6 Reference is made, in connection with the exclusions of Par. 4, to the separate codes for testing:

(a) Displacement Pumps
(b) Centrifugal and Rotary Pumps
(c) Reciprocating Displacement Compressors and Blowers
(d) Centrifugal and Turbo-Compressors and Blowers
(e) Refrigerating Machines and Plants
(f) Locomotives.

Reference is also made in general to other codes prescribing items forming part of this code, which must be considered in connection with it. All directions in these codes, noted below, applicable to this one must be followed:

(g) General Instructions
(h) Definitions and Values
(i) Instruments and Apparatus
(j) Fuels.

Object

7 In accordance with the "General Instructions," the object of the test, and if more than one, then each separately, should be determined and recorded.

This code is limited to tests in which the object is of a commercial nature. It excludes all tests forming part of experimental investigations, research or development. But while no engineer undertaking tests of a research or development nature needs any code if he is competent to make such investigations, it will usually be found that parts of such research work will be aided and in no way hampered by following parts of this code. It is also in the interests of those branches of engineering, whose progress is based on experimental data, if any parts of an investigation are carried out in accordance with the code, and recorded in accordance with the code. Results so obtained are more easily comparable with the large numbers of tests always being carried out on the lines of the code. The research data then enter readily into the general body of knowledge of the internal-combustion engine.

8 Tests of the kind contemplated by this code and for which it has been prepared, are those in which the object of the test is *definition* of an engine by its performance characteristics.

9 When the object of the test is wholly or in part the determina-

tion of fulfillment of a contract guarantee, an agreement should be made before the test between the interested parties on all matters that involve any possible elements of uncertainty, or that may later be a cause of dispute, as noted in Par. 3 of the "General Instructions," and the points agreed upon should be stated in the report of the test.

10 Agreements between interested parties should also be made and recorded even when a contract guarantee is not involved, before undertaking any test in which an element of judgment is involved in the selection of any instrument, piece of apparatus, physical constant, test method, operation condition or other matter that will promote the accuracy, the value, conclusiveness or the general acceptability of the results when obtained. This matter is one of special importance in tests on internal-combustion engines because of their great variety.

11 Sub-objects of the main object may often be of value in improving the value of results obtained in the test for the main object and may themselves be made the subject of separate tests, but in all cases *only* when made the subject of previous agreement as to the nature of the sub-objects and the test procedure. Sub-objects of a test must be separately reported as such to clearly distinguish them from the main object, and it is advisable that reasons be given for making such special tests. This is especially important when the special test for the sub-object is to be conducted at the same time as the test for the main object. Some sub-objects that may be expected to arise in connection with code tests of internal-combustion engines are listed below, but no special instructions concerning them are included in this code. Selection is left entirely to the judgment and agreement of the test engineers, but none of these sub-objects will be considered as tests made "according to the A.S.M.E. code," unless specifically added to the requirements by agreement and so marked in the report. It is recommended as good practice that they conform as far as possible to such parts of this and other codes as may be found applicable, especially those enumerated in Par. 6.

(*a*) Exhaust-gas analysis, with special reference to the determination of air not utilized by the engine in combustion, and of unburned fuel or combustible
(*b*) Exhaust-gas temperature, with special precaution to get accurate results in view of high velocity of gases, intermittent flow, and cooling conditions in exhaust ports and pipes, determined with special reference to equalization of load between cylinders of multi-cylinder engines, or accuracy of adjustment of combustion conditions, or percentage of fuel heat discharged in the exhaust
(*c*) Amount of air taken into an engine, with special reference to the volumetric efficiency and the completeness or incompleteness of the charging as a factor in actual as compared to possible power developed
(*d*) Properties of liquid or gaseous fuels with reference to suitability for use in the engine, or with reference to identity of the fuel as to some specification
(*e*) Determination of variations in the quality of lubricating oil or its contamination by use, especially by fuel or fuel products, and particularly for engines provided with a fixed amount of lubricant successively reused
(*f*) Nature of solid deposits in combustion chambers, on pistons, valves and ports, resulting from use and originating in fuel or lubricant or in solids carried by the air
(*g*) Amount of air required to start an engine provided with air-starting equipment, in relation to the capacity of starting compressors, especially for engines that must be frequently maneuvered in service
(*h*) Electrical starting requirements of engines using electricity for starting on heaters or electric motors, in relation to generator and storage battery
(*i*) Amount and pressure of air required for air-spraying apparatus of air-injection oil engines using fuel oils, in relation to the spray-air compressor capacity
(*j*) Power consumed by each or all of normally attached auxiliaries, with or without other operative characteristics of these auxiliaries, which include electric generators or magnetos, storage batteries or complete electric ignition apparatus, jacket-circulating pumps, direct or radiator cooling fans, lubricating-oil and fuel-oil pumps, starting and spray-air compressors, scavenging pumps of two-cycle engines, attached fuel and lubricating-oil heaters and coolers
(*k*) Smoke quantity and color or density, and particularly when smokelessness in some degree is a matter of importance or of specification.

Measurements

12 The measurements that must be made in a performance test of an internal-combustion engine will be the following quantities:

(*a*) Cylinder diameter, stroke and clearance volume of working cylinders.
(*b*) Diameters of piston rods and tail rods of working cylinders of double-acting engines
(*c*) The brake-horsepower or shaft-horsepower output
(*d*) The kilowatt output if engine is direct-connected to a generator
(*e*) The speed in revolutions per minute
(*f*) The horsepower to drive the water-cooling pump and fuel-pump (if any)
(*g*) The horsepower to drive the independent scavenging pump or blower
(*h*) The horsepower to drive the independent injection air compressor
(*i*) The amount of fuel supplied: cubic feet of gas for gas-burning engines, or pounds of liquid fuel for liquid-fuel engines. If more than one kind at the same time, the amount of each kind
(*j*) The calorific value of the fuel, high value.

13 The measurements which may be made in addition to those required by Par. 12, will be some or all of the following as may be agreed in advance by the test engineers:

(*a*) Cylinder diameters and strokes of injection air compressor
(*b*) Two-cycle engine scavenging pump diameter and stroke
(*c*) Diameters of piston and tail rods of scavenging pumps of two-cycle engines
(*d*) Diameters of piston rods and tail rods of injection air compressor
(*e*) The indicated horsepower
(*f*) The number of explosions per minute, or fuel injections per minute, or in general, combustion times per minute, for each and for all working cylinders
(*g*) The spray-air pressure of air-injection oil engines
(*h*) The exhaust back pressure at the engine
(*i*) The scavenging-air pressure of two-cycle engines, constant or maximum values
(*j*) The manifold vacuum of carburetor engines
(*k*) The jacket-water or oil-supply pressure at the main, and if jackets are divided with separate supplies, the pressure at the supply point or branch pipe to each
(*l*) The jacket water or oil back pressure at the main outlet, or if jackets are divided with separate discharges, the pressure at the outlet of each
(*m*) The pressure or vacuum or the hydraulic head, positive or negative of the supply of liquid fuel at the carburetor connection of carburetor engines, and at the injection-pump suction of injection oil engines
(*n*) The pressure or vacuum of the gas supplied to gas-burning engines at the mixing valve connection
(*o*) The total pressure, static and velocity of cooling-air supply of air-cooled engines
(*p*) Barometric pressure
(*q*) Atmospheric humidity
(*r*) The pressure of lubricating-oil supply to bearings of engines lubricated by pump forced-feed circulation
(*s*) The temperature of the atmospheric-air supply
(*t*) The temperature of the fuel for gas at the mixing valve, or for liquid fuel at the carburetor or injection-pump suction
(*u*) The temperature of the jacket water or oil as supplied to the engine as a whole, or if jackets are divided with separate supplies, the temperature of each separate supply
(*v*) The temperature of the jacket water or oil leaving the engine as a whole, or if jackets are divided with separate outlets, the temperature at each outlet
(*w*) The temperature of the scavenging air of two-cycle engines
(*x*) Temperature of injection air
(*y*) The temperature of the lubricating oil supplied to the engine at as many points as there are different supplies of pump-circulated lubricating oil, or in the crankcase of engines without pumps or having pump deliveries that do not permit of temperature measurement
(*z*) The temperature of the cooling air supplied to an air-cooled engine
(*aa*) The amount of lubricant consumed, pounds
(*ab*) The amount of jacket water or oil supplied, pounds, for engines as a whole, and when jackets are divided for each if both supply and discharge are separate
(*ac*) Amount, pounds or cubic feet, of cooling air supplied to air-cooled engines
(*ad*) Amount, pounds, of jacket water evaporated in jackets of hopper-cooled engines
(*ae*) Amount, pounds, of injection water supplied internally to cylinders of some oil engines, as a liquid or as steam
(*af*) The compression pressure in cylinders when hot and cold, at normal or at reduced speed at wide-open throttle.

14 In preparing a list of measurements from the items of Pars. 12 and 13, to be made preparatory to the planning of the log, and as a guide to their selection, it must be noted that in the above lists of measurements there are provisions for three groups:

(*a*) Measurements required for the determination of results required for this code, namely, those of Par. 12.
(*b*) Measurements to indicate the maintenance or variation of important operating conditions which might be described as the steady state required for the test prescribed, but which measurements do not themselves enter into the results except as specifying conditions under which the results were obtained. For example,

this is the case with all jacket water or oil and all lubricating-oil measurements of pressure, temperature and quantity. These are included in the list of Par. 13.

(c) Measurements for one or more of the determinations required by such sub-objects listed in Par. 11, as may be made the subject of an agreement by the interested parties. These are included in the list of Par. 13.

INSTRUMENTS AND APPARATUS

15 Directions regarding the application, use and calibration of instruments and apparatus, do not form part of this code. Such information is given in the Code on Instruments and Apparatus, supplemented by that on Definitions and Values, in which will also be found statements on scope and limitations of use, and on accuracy.

The instruments and apparatus required for a performance test of an internal-combustion engine as prescribed by this code will include some or all of the following:

(a) Scales with or without special auxiliary apparatus for weighing liquid fuel, with or without tanks to be used in coöperation
(b) Gas meters for measuring gaseous fuel, or gas-metering methods with indirect observation apparatus
(c) Gas calorimeters for determining the heating value of gaseous fuels
(d) Baumé oil hydrometer for petroleum liquid fuels, and for indirect determination of calorific power
(e) Pressure gages and mercury or water columns for measuring small pressures and vacua
(f) Thermometers
(g) Barometers
(h) Gas-engine and oil-engine indicators for working cylinders and steam-engine indicators or special low-scale springs for cylinders of two-cycle scavenging pumps and low-pressure cylinders of injection air compressors
(i) Pressure-indicating or recording instruments for compression pressures or injection pressures in cylinders
(j) Planimeters
(k) Tachometers, revolution counters or other apparatus for measuring speed or number of fuel admissions per minute
(l) Absorption dynamometers of appropriate type for the horsepower, speed and torque of the engine to be tested, especially hydraulic brakes and electric dynamometers
(m) Appropriate electrical instruments and apparatus, if the engine is direct connected to a generator, to provide a suitable electrical load and to measure it.

16 In making a selection of instruments suitable for the measurement of quantities required by the performance test under this code, and constituting its main object per Pars. 7 and 8, it is necessary to exercise considerable latitude of judgment in view of the variety of internal-combustion engines noted in Par. 3, to insure proper relation of selected instrument to the conditions of measurement to be made. Some suggestions are offered below as a partial guide to such selection.

17 Indicators cannot be used at all on some internal-combustion engines and in other cases only within limits. In no case can an indicator be regarded as a precision instrument on an internal-combustion engine to the same degree as on a reciprocating steam engine. Some special cases are noted:

(a) When the engine speed exceeds 400 r.p.m. an indicator must not be used for determining the cylinder mean effective pressure of an internal-combustion engine. This excludes it and the determination of indicated horsepower for all engines of Par. 5(c) and 5(d), and all engines of Pars. 5(a) and 5(b) operating over 400 r.p.m.
(b) When the engine speed exceeds 400 r.p.m. optical indicators may be useful as a means of adjustment of valve or spark timing, but have no other value, and are of no use even for such adjustments in the case of multi-cylinder engines
(c) On all hit-and-miss-governed engines the indicator must not be used for determination of the cylinder mean effective pressure for indicated-horsepower determinations, thus excluding such determinations from tests of hit-and-miss-governed engines
(d) When indicator cards taken even at speeds of 400 r.p.m. or less are not constant in shape and area over long periods of time while a constant load is maintained, the indicator must be rejected as a means of determining cylinder mean effective pressures though it may be used as a means of adjustment of timing, especially as a guide to equalizing the timing for multi-cylinder engines or the two ends of a double-acting cylinder. The test as to constancy of area shall be ± 2 per cent, so that when the largest area differs from the smallest area by 4 per cent or more of their arithmetical mean, all shall be rejected. At various odd intervals of time, at least ten diagrams shall be taken on one card in addition to those taken at regular intervals, for comparison as to constancy
(e) When indicator cards taken even at speeds of 400 r.p.m. or less are apparently constant in area, according to the conditions (d), they may still be useless as a means of determining cylinder mean effective pressure and indicated horsepower, when the cylinder pressures are very high, the spring scale large, 500 lb. more or less, and the whole measured card area at the same time is very small. Under these conditions the precision will be very low and the indicated horsepower much in error. Just what set of conditions will produce a result bad enough to reject must be left to the judgment of the test engineer, with the suggestion that the accuracy of planimetering the smaller area be used as a basis of judgment. This condition makes it hopeless to undertake determinations of indicated horsepower for many oil engines of the high-pressure type, developing only small mean effective pressures
(f) Even in the cases where the indicator cannot properly be used as an instrument for measuring mean cylinder pressures and indicated horsepower, it can be usefully employed as a means of adjusting and equalizing the cylinder compression, the adjustment of main valves, the point of ignition in electrically ignited engines, of spray-valve timing of Diesel oil engine, or the injection-pump timing of injection oil engines with direct pump injection
(g) When the conditions of proper use of indicators for mean-effective-pressure determinations are all fulfilled, no indicated-horsepower determination shall be made unless a separate indicator is used on each working cylinder of a multicylinder engine (each end).

18 Brakes or absorption dynamometers when used must be suitable for the engine to be tested, in capacity, in speed-torque relations, and in ability to maintain an adjustment without necessity for constant hand manipulation to hold scale beam steady.

(a) For testing all engines of Par. 5(c) and (d), nothing but an electric dynamometer shall be used to determine brake horsepower
(b) For brake-horsepower tests of engines of Par. 5(b), the electric dynamometer shall be used, or hydraulic, if reversing tests are to be run. On engines of this class of large size and lower speed, hydraulic brakes of the type in which brake torque varies with the nth power of the speed, and in which n is equal to or greater than 1.5, shall be used as the preferred form.
(c) Other forms of brake may be properly used with engines of Par. 5(a) and so also when available may the hydraulic type and the electric dynamometers above described
(d) When brakes of any kind cannot be mounted directly on the engine shaft without other supports, due precautions must be taken, per instructions in the Code on Instruments and Apparatus, to avoid errors due to these supports
(e) In no case may a brake driven by a belt or otherwise than by direct coupling to or mounting on the engine shaft, be used for engine brake-horsepower measurements
(f) With due precautions and under proper provisions brake-horsepower determinations may be made by the indirect or substitution method, and this is important because in some cases it is the only means available. According to this method the engine may be tested with a load such as a propeller (air or water type), a club or a fan, which propeller or fan may later be, or previously have been, tested for its speed-torque characteristic curve, and the horsepower of the engine determined by reading from this curve the horsepower for the speed maintained by the engine. The special precautions referred to relate to assurances of identity of conditions of flow through and resistance of the propeller or the fan under the two separate tests of use and of calibration. This is so difficult that none but test engineers of special experience should undertake it. In no case can results of test-stand torque alone be acceptable in brake-horsepower determinations for an engine.

19 In measuring speed, the choice of instruments is determined by the character of the test carried out. Continuous speed counters may be used only for slow-running engines, where a constant speed of considerable duration is maintained. Hand speed counters placed directly against the engine shaft may be used, if handled carefully and well made. Tachometers may be used of the centrifugal, liquid pumping, or magnetic type, but these must be carefully calibrated and records of recent calibration must be available. Tachometers must be connected by a reliable tachometer shaft or by positive gearing to the engine shaft, and in no case should belting be used as a connecting link.

20 The heating value of fuels to be used in calculations of results of tests of internal-combustion engines must be the "high value" products condensed or the direct reading of a water calorimeter properly used in accordance with the procedure specified by the Code on Fuels.

Accordingly the following recommendations are made:

(a) When gaseous fuel is burned in an engine under test, a standard form of gas calorimeter shall be used as one of the instruments of the test, and its determination shall be used as the heating value of the gas as supplied. Calculations of heating value from the gas analysis are not permissible according to the code, but with all details of apparatus, methods and physical constants involved may be made the subject of previous agreement
(b) When liquid fuel is burned in an engine under test, its heating value shall be determined in a standard bomb calorimeter by a recognized physical or chemical laboratory, the selection of which

should be a matter of previous agreement, and in the report the "high value" should be used in calculating final results. In no case shall such a determination be part of the duty of a test engineer, nor should his results be regarded as acceptable

(c) The heating value of gasolines and kerosenes may be estimated by the Sherman & Kropff formula, modified by Strong, from the Bé. reading without the bomb test, if such procedure is made the subject of previous agreement.

21 Gas measurements for engine burning gaseous fuel must be made with meters or by methods yielding the greatest possible accuracy consistent with availability and cost in the large sizes.

In no case can the results of proportional meters be regarded as satisfactory, nor those of vane meters of the anemometer type. Within the limits of size and cost, positive displacement meters are to be preferred, but these are not available for measurements of large capacity.

Large capacity measurements are best made by means of one of the various types of flow-rate measurements, and that one, applied to mixed gases, should be used that requires the simplest and most accurate determination of physical or chemical properties.

When physical or chemical properties of a mixed gas must be determined for use in a metering calculation, even if only gas density direct or computed from the analysis, a recognized chemical laboratory shall be agreed upon to make the determination and its report shall be accepted and used. In no case shall the test engineer make a determination of physical or chemical properties of gases, nor shall his results be acceptable if he does so.

If measurements of volume of injection air or of scavenging air are desired, the orifice-flow method will be sufficiently correct if used as prescribed in the Code on Instruments and Apparatus, but the formula and conditions for such test must be agreed upon in advance between the engineers.

22 Liquid fuel supplied to an engine should never be measured by volume; it must be weighed directly as used. Combinations of weighing and volume measurements are acceptable if the volume of the tank itself is not the measure but only a reservoir from which the engine draws a supply, starting with a predetermined level marked by a hook gage or on a glass, and a weighed quantity subsequently supplied to restore the original level. In this case the weight is the measure and the result acceptable if proper precautions are used to limit the weight error of reading levels to something less than the error of the scale weighing.

In no case shall meters be used to measure liquid fuel supplied to an engine.

When volatile fuels are used, and especially when heavy liquid fuels containing light volatiles must be heated to make them flow, precautions must be taken to prevent losses of weighed fuel by evaporation, and the main supply must be protected against evaporation that may fractionate or concentrate it and change its quality with time.

Preparations

23 Before proceeding with a test, Pars. 4 to 8 of the "General Instructions" should be reviewed. The dimensions and physical conditions of all parts of the engine should be determined and recorded. The same should be done for all parts external to the engine to be tested, the condition of which might effect the success of the test in many ways.

24 Things external to the engine should always be given attention first, and if on inspection and preliminary trial anything should be found that might impair the value of the test, it should be corrected before starting or even before the condition of the engine is examined. In view of the great variety of engines and operating arrangements, it is impossible to enumerate all of these things, but for their suggestive value a few are noted below:

(a) Jacket-water supply should be assured in proper quantity, of proper cleanliness as to freedom from sediment, non-corrosive, and of a kind that will not deposit scale in the jackets when its temperature is raised. It is necessary also to arrange for as nearly constant a supply temperature as possible to maintain a steady state as to temperature of heated engine parts. The exceptions to this are: air-cooled engines; engines with boiling hopper jackets or with thermosiphon circulation to tanks, or with any sort of circulation of a fixed amount of water between jackets and a radiator or cooler. In these cases a proper supply of cooling water or air for the cooler or radiator must be assured. Engines operating with oil in jackets are included in the last group. Air-cooled engines must be assured of a supply of cooling air proper in amount, velocity and direction as well as temperature

(b) Engines operating with electric ignition, especially in the larger sizes, may be dependent on an external supply of current for the ignition system, or especially in small engines be supplied from primary or storage batteries. Assurance of continued supply at proper voltage for the whole test must be provided, and the most reliable means is an alternate source

(c) When liquid fuel is to be used, there should be a sufficiently large supply of the grade to be burned to last for the whole period of the test, and in the case of viscous or semi-viscous oils, which do not mix well without heating, special care should be taken to assure the mixing of new oil supplied to the tanks with that already in the tanks. This is especially important for that group of oil engines most sensitive to grade of oil

(d) Lubricating oil in sufficient quantities to complete the test should also be available before starting. When the lubricating system includes a tank or sump, especially when it is of considerable capacity, this should be drained and new oil provided or new oil in sufficient quantities properly mixed with it to prevent any changes during the test, other than those normal and incident to its operation.

25 If the engine is by previous agreement to be tested "as is," or in whatever condition it may happen to be, there is nothing further to be done before starting the test except to determine all those dimensions required to identify the engine, or necessary for the calculation of results.

On the other hand, and normally, the engine should first be put in proper condition to perform in a manner proper and normal to it, so that the test results will be not only a measure of what it did do, but also of what it is capable of doing.

In the absence of any agreement to the contrary, it will always be assumed that before starting the test the engine will be put in proper condition so far as can be done by cleaning, by stoppage of all leaks and by adjustment, including replacement of small parts, such as spark plugs or spray valves. Some suggestions are given as a guide to these several groups of items, but these must not be regarded as a substitute for the judgment of the test engineer, who should in all cases record not only the condition in which the equipment was found, but also everything done to change the condition.

26 Dimensions and other data not necessary for calculating test results but useful to identify an engine or to increase the value of future comparative analyses may properly include some items of its commercial specifications not properly classifiable as dimensions. Among such items, including some that are necessary for calculating test result, are:

(a) Bore, stroke, number of working cylinders and in the case of two-cycle engines, the same information for scavenging pumps, with notes as to single- or double-acting arrangement for either or both and notes regarding injection air compressor if used

(b) Dimensions of other principal fixed and running parts, diameter and length of all important bearings and pins, including piston rods and tail rods

(c) Dimensions of certain minor parts, fixed and running parts having important functions, such as valve lift, port area, area through mixing valves of gas-burning engines, carburetor choke area and nozzle sizes, injection-pump plunger bore and stroke, push-rod or valve-rocker clearances

(d) All items of adjustment and timing and for each cylinder of multi-cylinder engines such as spark of electric ignition engines, spray valve of injection oil engines when mechanically operated, opening and closing angles, injection pumps of injection engines delivering directly to spray valves not mechanically operated, start and stop angles, normal pump by-pass valve, timing of injection oil engines, inlet and exhaust valves of four-cycle engines opening and closing, all special valves of two-cycle engines

(e) All nameplate information, together with important identification items of specifications especially concerning attached auxiliaries, nature, size, capacities, with proper working pressures, temperatures or other items of operation or adjustment

(f) Certain dimensions in addition to the above, not matters of identity nor necessary for calculation of test results but of importance in judging the condition of the engine as a machine and useful in judging the value of the results of the test. Here are included all items of alignment, clearances of bearings, pins, rods and slides, pistons in cylinders, rings in grooves, valve stems in guides, pump plungers in pump body, throttle in seat, together with variations from straightness or roundness of cylinders, pistons and other parts.

27 Cleanliness, especially internal, is of great importance in the operation of internal-combustion engines. Attention should be given, among other things, to the following suggestions:

(a) Jacket surfaces on the heat-receiving side must be free from water scale, rust or other deposits, including carbonized oil, if oil is used

in place of water. Any deposit will cause the engine to operate unduly hot and may prevent operation entirely

(b) Combustion-chamber walls, including piston heads and all inward-facing parts, such as spark plugs, spray valves, air starting valves, relief valves, as well as inlet and exhaust valves and the ports of four-cycle engines, and the ports of two-cycle engines, should be free from deposits, especially carbon, oil, gum or tar, and solids derived from uncleaned air. This also applies to cylinder walls and piston rings

(c) The lubricating-oil system should be free of all deposits of whatever kind, and all flow passages freely and fully open, especially with circulating forced-feed systems

(d) The exhaust system, including expansion chambers, mufflers and pipes should be clean and free and so arranged as to not develop excessive back pressure. Other engines exhausting into the same system must not interfere with the engine under test. It is always preferable however that no other engines should exhaust into the system of the engine under test

(e) Fuel-supply and regulating systems must be clean and free of sediment, tar or other foreign matter, and passages fully open, especially for liquid-fuel engines, at the carburetor or injection pumps.

28 Leakages must be located and corrected. Among important leakages to be investigated attention is called to the following:

(a) Cylinder leakage outward, lowering the compression and efficiency or possibly preventing operation. These leakages may be best checked by an indicator if the engine is one suitable for indicator use. When there is any clear space between the compression and expansion lines of a card taken when there is no combustion and when cooling water is not running then it may be assumed that leakage is excessive. In this case, and in cases where an indicator cannot be used to check leakage, the several possible sources of such leakage must be separately checked. These are piston ring, cylinder, cylinder-head gasket, air starting valve, relief valve, spray valve or spark-plug seat, inlet or exhaust valves of four-cycle engines, or air scavenging valves of valve-scavenging two-cycle engines.

(b) Leakage into the cylinder may occur from the jackets through bad joints, cracks or porous spots and blowholes in the castings, compressed air from the starting air system through leaky air starting valves, fuel oil past spray valve at improper times and high-pressure spray air when air spraying is used in oil engines

(c) Miscellaneous leakages not into or out of the cylinder but elsewhere may be sought; in the manifold system of carburetor engines anywhere between carburetor and inlet-valve seat, especially at flanges and valve-stem guides; fuel oil in injection oil engines at pump valves, pump plunger, oil-delivery pipe or spray valve, lubricating oil at pump, tanks or in piping, spray air at compressor storage bottles, valves or piping, starting air at compressor storage reservoir, valves or piping. Insulation of electrical circuits must be checked as a leakage item.

29 Adjustments must be corrected if found to be wrong.

Operating Conditions

30 The operating conditions conforming to the object in view should prevail as pointed out in Par. 19 of the "General Instructions." If it is a matter of agreement that the engine is to be tested in whatever condition it may be, and under whatever conditions may prevail, then there is nothing to be done except to keep a record of all these conditions, with special emphasis on variations of every item that might effect the operation, or be useful in a subsequent effort to explain results.

On the other hand, if by agreement operating conditions are specified more or less completely, then instruments shall be used and observations made to establish their maintenance or variations.

In either case a record should be made and included in the final report.

This matter of operating conditions prevailing during the test is of very great importance in internal-combustion engines, not only because of their great variety and the corresponding variety of conditions normal to any one sort of engine, but also because the internal-combustion engine is self-contained, actually or essentially, and sensitive to many conditions within itself, not noticeable unless sought. Many of these have already been noted under "Preparations," as concerned with supplies, flows, leakages, clearances and fits or adjustments, but in addition to these there always arise questions of propriety of conditions of test in relation to conditions of service.

Doubt and confusion will always result in internal-combustion engine tests if any assumption is made to the effect that the conditions of test shall be "normal." If the word "normal" is used at all to describe the conditions, it must be defined by agreement. An agreement defining the conditions of the test is regarded as essential to all internal combustion engine tests. The definition should include all the items necessary in two groups noted below, one concerned with conditions in relation to service, and the other purely matters of test procedure.

31 Operating conditions to be maintained during the test are the ones most uncertain as will be clear from the following note:

Aircraft engines must normally work in altitudes varying from sea level to perhaps 30,000 ft., and in temperatures varying from highest in summer in the tropics, perhaps 120 deg. fahr., to the coldest known, under 50 deg. fahr. below zero, and in any weather—dry, fog clouds, rain and snow. They must also operate well at any angle of inclination and even upside down but always with an air-propeller load. In view of the fact that the only tests contemplated under this code are fixed block tests, it is clear that service conditions cannot be closely reproduced and only approximated even in the special altitude room of the Bureau of Standards with its air-refrigerating apparatus

Engines for land vehicles are essentially variable in speed and variable in load in normal operation, and must instantly respond to controls that are constantly and suddenly varied in heavy street traffic, or perhaps maintained for long periods of time in tractor or rail operation, and rarely develop maximum horsepower though frequently called upon for maximum torque. There can be no such thing as normal horsepower or speed for such engines and acceleration is quite as important as horsepower. They must, furthermore, operate on a fixed supply of jacket water or oil with an air-cooled radiator or directly air-cooled, so that external wall temperature varies not only with engine load but with vehicle speed, with weather and with climate.

As used, especially with tractors, the air supply is usually dirty, and may be heavily laden with gritty dust, requiring the use of more or less effective dust separators or air washers. Again, it is clear that service conditions cannot be maintained during the block tests contemplated by this code.

Marine engines, ranging from small single and multiple cylinder gasoline engines, often of very high speed, especially for racing boats with gear drives and clutches, to the direct-coupled large reversing low-speed Diesel oil engine of motorships of 2000-3000 hp., always with a propeller load, also operate under service conditions that cannot be reproduced in block tests.

Even stationary engines as a class while normally operating under conditions easier to reproduce in the block tests of tests in place according to this code, do also include considerable variety as to what is normal. Some of these, especially the smaller ones, such as farm engines or home lighting sets, operate for only short periods of time, and rarely if ever at full load. Others, especially those for irrigation pumping, may work continuously at the maximum possible load 24 hours per day for the irrigation period, of perhaps three months, and then be shut down for the rest of the year. Still others, especially those operating town water works or oil-pipe-line pumps may operate at full load 24 hours per day for a whole year or more. Still others, notably the generating units of central stations, must meet the widest and most sudden fluctuation of electrical load without varying in speed enough to affect voltage or synchronous operation of alternating-current systems.

The importance of agreement on these matters should be clear from these citations but the details must be left to the judgment of the test engineer.

32 Operating conditions during the test include mainly matters of load and speed to be maintained, with other points incidental to these. These should be agreed upon in all details, and should not be inconsistent with the conditions prescribed below:

(a) Engines of the stationary class, including all engine-driven generator sets, Par. 5(a), shall be tested at constant speed under governor control or as near constant as the governor will maintain it, and at whatever load in horsepower or kilowatts may be required by agreement or specific object of the test

(b) All engines for the propulsion of land vehicles, Par. 5(d), except such tractor engines as are fitted with speed governors and operate normally under governor control, shall be tested with throttle wide open, with brake torque regularly varied from nothing to a maximum and back to nothing, at whatever speeds may result, and the horsepower-speed curve typical of the engine shall be determined instead of the horsepower at any given speed. In no case should a *safe* speed be exceeded and when the highest speed used is the safe limit, it should be so stated. The maximum torque applied shall in all cases be greater than that which will produce maximum horsepower unless the speed required for this is too high to be safe

(c) Marine engines, Par. 5(b), and aircraft engines, Par. 5(c), may be tested according to the conditions prescribed for engines of land vehicles, in all respects according to conditions prescribed for stationary engines except that the speed shall be maintained by the brake torque and not by a governor. Marine engines may also be tested at constant speed for full-load operation fixed by their propellers.

Special attention should be given to questions of safety that may arise during operation, such as excess speed, or torsional vibrations at a given speed within the normal range, and the procedure to be adopted in such cases should also be included in the agreement.

Starting, Stopping and Duration

33 Before recording the test observations it is essential that an internal-combustion engine, together with all attachments and

appurtenances, be brought to a condition of *steady state.* The test cannot be considered as having started until the engine has been in operation for a sufficiently long time to have attained its steady state for the conditions of the first run, and until preliminary observations have been made and recorded to prove that such steady state has been reached. If successive runs are to be made, each under some different conditions, these must be repeated for each run.

The preliminary observations establishing the attainment of a steady state for the conditions of operation of the test or each run of the test, must be made a part of the record.

For an internal-combustion engine itself this is a matter of utmost importance, because the combustion chamber is a furnace in which heat is developed at a given rate, depending on the fuel burned per minute in each cylinder (or each end), and in which the metal temperatures vary with this rate of combustion. Metal temperatures vitally affect the performance of the engine especially those of cylinder, cylinder head, and piston, with all attached parts, and in addition those of all bearings.

The length of time necessary to establish the steady state will be different in engines of different class, and in any one class different for different sizes. In general, the weight of metal in contact with the combustion chamber directly or indirectly through thermal conduction will determine the length of time necessary, but the rate of combustion in B.t.u. per hour per square foot of cylinder area will also be a factor. The greater the metal weight and the lower the rate of combustion the larger the time necessary to reach the steady state. While jacket-water or oil temperatures are important factors, they are not the controlling ones. Lubricating-oil temperature in the sump or leaving the bearings in a circulating system, is a guide to steady state of both bearings and of combustion-chamber metal, but not a conclusive one. In no case shall an engine be regarded as having attained its steady state unless jacket and lubricating-oil temperatures are substantially constant.

The means whereby the attainment of the steady state is proved must be a matter of agreement, but the time of operation itself for the preliminary period may be substituted.

In no case shall steady state for the first run be regarded as established in a shorter time than one hour after the operating conditions have been imposed and before test observations have started. For successive runs at other conditions the minimum time for any engine shall be ten minutes, the actual time being determined by the extent to which conditions are changed in successive run. Maximum time to reach the steady state for any internal-combustion engine shall not be taken as greater than 24 hours, which may be regarded as permissible for the largest sizes of low-speed Diesel engines for motorships and double-acting stationary gas engines.

34 The duration of the test after the establishment of steady state for the set operating conditions shall be a matter of previous agreement, but should be greater for engines where reliability is a question of importance and which require the longest time to reach the steady state.

In no case shall the length of run be less than the period required to reach the steady state, subject to the additional condition that the length of run shall be great enough to insure the accuracy of fuel measurement within 1 per cent, except when gaseous fuel is metered and when metering accuracy is not improved by lengthened runs.

In some cases it may be found desirable to make a physical inspection of engine parts after the test to determine injury due to operation, but only when agreement has been made as to details should this be done.

Records

35 The general data should be recorded as pointed out in Pars. 20 to 30 of the "General Instructions." Instruments should be read at least quarter-hourly when the conditions are uniform, and oftener when there is much variation. Indicator cards, if taken, must be taken from every working cylinder of multi-cylinder engines. If there are wide fluctuations in readings, they should be shown by recording instruments.

Each indicator card should be marked when taken, with the number, date, time, scale of spring, number and kind of cylinder and end of cylinder, if double-acting.

The log should contain the records of the readings of all instruments, and these readings should be obtained at practically the same time as the indicator cards, if any, are taken.

If indicator cards are taken, the areas, lengths, mean effective pressures, compression pressures and maximum cylinder pressures, should all be recorded in the log. One or more sets of specimen indicator diagrams should be carefully selected for inclusion in the record. If, after taking indicator cards they are rejected, because of excessive fluctuation in area or insufficient area with high pressures for accuracy, a sample set of the rejected cards shall be included in the record with the data to support the rejection and justify the elimination of indicated horsepower from the results.

Calculation of Results

36 The calculations necessary for deriving results from observations or from physical constants should not be undertaken without previously consulting Pars. 31 to 35 of the "General Instructions," and the Code on Definitions and Values.

37 *Fuel Consumption.* For liquid-fuel engines the actual fuel measured is stated in pounds in the report of the test, and is subject to no corrections.

For gaseous-fuel engines the cubic feet of gas at whatever pressure and temperature prevailed, indicated or recorded by the meter or calculated from the reading flow-rate devices, is stated in the report of the test. This is to be corrected for the pressure and temperature at which the gas calorimeter burned the gas. The correction is to be made by multiplying the cubic feet of gas measured by the ratio of the absolute pressure at the meter to that at the calorimeter and by the ratio of the absolute temperature of the gas at the calorimeter to that at the gas meter. The product is the cubic feet of gas supplied to the engine measured at gas-calorimeter pressure and temperature.

38 *Heat Consumption.* The number of heat units consumed by an engine per hour is found by multiplying the consumption by the heating value. The heating value for gaseous fuels is stated in the report of the test as found by the gas calorimeter, in B.t.u. per cubic foot, high value. The heating value of liquid fuels is stated in the report of the physical or chemical laboratory engaged for the determination, in B.t.u. per pound of fuel, high value.

39 *Indicated Horsepower.* If indicated-horsepower determinations have been specified in the agreement before test and when the indicator can be used, and when in addition after using it the indicator cards are found to be acceptable as to accuracy for determining mean effective pressure, per Par. 16, then the indicated horsepower shall be calculated as follows:

For four-cycle engines the indicated horsepower for each single-acting cylinder and for each end of each double-acting cylinder shall be found by using the formula—

$$\text{I.hp.} = \frac{PLAN}{2 \times 33000}$$

where P represents the mean effective pressure in pounds per square inch; L the length of the stroke in feet; A the area in square inches of the piston less the area of the piston rod or tail rod, if any; and N the number of revolutions per minute. The total indicated horsepower of a double-acting cylinder is the sum of the horsepower developed in the two ends, and the indicated horsepower of a multi-cylinder engine is the sum of the horsepower developed in each cylinder.

For two-cycle engines the indicated horsepower for each single-acting working cylinder, and for each end of each double-acting working cylinder, shall be found by using the formula—

$$\text{I.hp.} = \frac{PLAN}{33000}$$

where the symbols have the same meaning as above. The total indicated horsepower of all working cylinders is the sum of the horsepower developed in each cylinder, and in each double-acting cylinder it is the sum of the horsepower developed in each end.

The mean effective pressure, P, should be found by dividing the area of the diagram in square inches, as determined with a correct planimeter, by the length of the diagram, in inches, and multiplying the quotient by the average corrected scale of the indicator spring.

Accuracy tests must be applied to determine the acceptability of the mean effective pressure thus determined, especially when cylinder pressures and spring scales are high (as for injection oil engines) and card areas small, as is more usual for two-cycle engines of smaller size.

40 *Brake Horsepower.* The brake horsepower is found by multiplying the net force, W in pounds on the brake arm, by the circumference of the circle whose radius is the horizontal distance, L, in feet between the center of the shaft and the bearing point or weight center at the end of the brake arm, and by N, the number of revolutions of the brake shaft per minute, and dividing the final product by 33,000.

$$\text{B.hp.} = \frac{2\pi LWN}{33000}$$

Reference must be made to the Code on Instruments and Apparatus for descriptions of brakes, especially the hydraulic and electric dynamometer types, referred to in Par. 17 for methods of applying them, and especially for methods of correctly determining the net force W from the gross force, and for incidental or special errors in brake use and calculations.

41 *Electrical Horsepower.* The electrical horsepower of a generator is found by dividing the output at the terminals expressed in kilowatts by the constant 0.7457. In the case of an alternating-current generator, the quantity of output determined whether expressed in electrical horsepower or kilowatts, should be the net output. When the power for excitation or ventilation is taken directly from the engine shaft, the net output is that indicated at the terminals. When the exciting current is obtained from the generator through a motor or from some outside source, the net output is found by deducting the current furnished as excitation from that delivered at the terminals. When the exciter is driven from the engine shaft, the engine supplies the belt losses and the exciter losses without being credited. When the exciting current is obtained from the generator through a motor, and the excitation current is deducted from that delivered at the terminals, the exciter losses are not credited. Where as with a separately driven exciter, it is really the exciter net output which is deducted from the power delivered at the terminals. In a close test these differences may be of some interest. It is regarded as important to have the basis of power determination definitely agreed to in advance to suit the particular case and to be suitable to local conditions prevailing.

42 *Thermal Efficiency.* The fraction of the heat consumption converted into work is the "thermal efficiency" and is found by dividing 2547 (B.t.u. equivalent to 1 hp-hr.) by the number of heat units actually supplied per indicated hp-hr., Par. 37. The quotient is multiplied by 100 to express the thermal efficiency in per cent. The formula is

$$\text{Thermal Efficiency} = \frac{2547}{HQ}$$

where H = heating value of the fuel (high value), B.t.u. per pound or per cubic foot and Q = amount of fuel supplied per indicated horsepower hour, pounds or cubic feet.

DATA AND RESULTS

43 The data and results should be reported in accordance with the form of Table 1 for horsepower tests made at constant speed, and in accordance with the form of Table 2 and chart, Fig. 1, for horsepower tests made over the whole speed range of a variable-speed engine. Lines may be omitted if not required for the object of the test, or new lines may be added for additional data desired. For marine engines either or both forms may be used.

TABLE 1 DATA AND RESULTS OF INTERNAL-COMBUSTION ENGINE TEST AT CONSTANT SPEED

GENERAL INFORMATION

(1) Date of test..........
(2) Location..........
(3) Owner..........
(4) Builder..........
(5) Test conducted by..........
(6) Object of test..........

DESCRIPTION, DIMENSIONS, ETC.

(7) Type of engine, two- or four-cycle, single- or double-acting, horizontal or vertical, if four cycle, the valve arrangement L, T, or I head, if two-cycle, the type of scavenging, if single-acting, whether crosshead or trunk piston, if multi-cylinder the arrangement of cylinders and cranks, gas or liquid fuel, and if liquid fuel, carburetor type, or other class name fixing manner of treating fuel, such as Hvid, Diesel, or solid injection for example..........
....

(8) Class of service, stationary and special feature, marine, aircraft or vehicle, and what kind..........
(9) Auxiliaries attached, such as magneto, fuel-injection pump, fuel-circulating pump, lubricating-oil pumps, jacket circulating pumps, scavenging pumps, spray-air compressor, maneuvering or starting air compressor, radiator fans, oil or fuel coolers or heaters..........
(10) Auxiliaries, independent or separately driven, and power..........
(11) Details of type, capacity, maker's name and other features of auxiliaries..........
(12) Rated brake horsepower of engine, or kw. of electric generating set, and speed..........
(13) Grade of fuel for which engine is designed, kind of gas or specification of liquid fuel, and what was used in test..........
(14) Special structural features for fuel utilization..........
(15) Special structural features of speed and power control, and governor or reversing gear..........
Number of working cylinders..........
(16) Diameter of all cylinders working, 4-cycle or 2-cycle..........in.
(17) Diameter of piston and tail rods of working cylinders..........in.
(18) Stroke of working cylinders..........ft.
(19) Head-end hp. constant for working cylinders, (stroke × net piston area ÷ 33,000)..........
(20) Crank-end hp. constant for working cylinders, (stroke × net piston area ÷ 33,000)..........
(21) Capacity of generator or other apparatus consuming power of engine..........
(22) Characteristics of generator,—d.c. or a.c., volts, cycles, phase....

TEST DATA AND RESULTS

(23) Duration of test..........hr.

Pressures, Average

(24) Barometric pressure......in. of mercury......lb. per sq. in.
(25) Spray-air pressure (air injection Diesel engines) average (say whether gage or absolute)..........lb. per sq. in.
(26) Exhaust back pressure..........in. of water
(27) Jacket water supply pressure..........lb. per sq. in.
(28) Manifold vacuum (carburetor engines)..........in. of water
(29) Gas pressure in main gaseous fuel....inches water..lb. per sq. in.
(30) Lubricating-oil pressure, circulating forced-feed system......
..........lb. per sq. in.
(31) Scavenging-air pressure average, two-cycle engines..lb. per sq. in.

Temperatures

(32) Engine-room temperature..........deg. fahr.
(33) Temperature of fuel..........deg. fahr.
(34) Temperature of main air supply..........deg. fahr
Location of thermometer..........
(35) Temperature of main jacket water or oil inlet..........deg. fahr.
(36) Temperature of main jacket water or oil outlet..........deg. fahr.
(37) Temperature at inlet of separate jacket..........deg. fahr.
(38) Temperature at outlet of separate jacket..........deg. fahr.
(39) Temperature of mixture at intake port (carburetor engine)
..........deg. fahr.

Fuel Properties

(40) Heating value of gas, high value..........B.t.u. per cu. ft.
(41) Heating value of liquid fuel, high value..........B.t.u. per lb.

Total Quantities

(42) Total gaseous fuel at meter pressure & temperature cu. ft
(43) Correction factor for gas (Item 29 × Item 33 + 460 ÷ Item 29 × Item 39 + 460)..........
(44) Total gaseous fuel at carburetor or atmospheric pressure....cu. ft.
(45) Total liquid fuel..........lb.

Hourly Quantities

(46) Total gaseous fuel per hour at calorimeter or atmospheric pressure and temperature..........cu. ft.
(47) Total liquid fuel per hour..........lb.

Heat Consumption

(48) Total heat in fuel supplied per hour (Item 46 × Item 40, or Item 47 × Item 41)..........B.t.u.

Indicator Diagrams

(49) Mean effective pressure, average, four-cycle..........lb. per sq. in.
(50) Mean effective pressure working cylinders, average, two-cycle
..........lb. per sq. in.

Speed

(51) Revolutions per minute..........r.p.m.
(52) Piston speed..........ft. per min.

Power

(53) Indicated horsepower of all working cylinders..........i.hp.
(54) Indicated horsepower of each single acting cylinder, or each end of each double acting four cycle
No. 1 head end..........i.hp.
No. 1 crank end..........i.hp.
No. 2 head end..........i.hp.
No. 3 crank end..........i.hp.
etc.

(55) Brake horsepower developed by whole engine by brake or dynamometer measurement .... b.hp.
(a) Brake mean effective pressure .... lb. per sq. in.
(56) Total horsepower of independent scavenging pump and injection air compressor .... hp.
(57) Net or actual brake horsepower of engine, (Item 55 − Item 56) .... b.hp.
(a) Net brake mean effective pressure .... lb. per sq. in.
(b) Net torque at 1 ft. radius equivalent to brake horsepower .... ft-lb.
(58) Friction and attached auxiliaries horsepower (Item 53–Item 55) .... hp.

Economy Results

Fuel consumption per i.hp-hr., gas (Item 46 ÷ Item 53) .. cu. ft.
Fuel consumption per i.hp-hr., liquid (Item 47 ÷ Item 53) .... lb.
(59) Fuel consumption per b.hp-hr.: Gas (Item 46 ÷ Item 57) .... cu. ft.
Liquid (Item 47 ÷ Item 57) .... lb.
(60) Heat consumed per i.hp-hr.: (Item 48 ÷ Item 53) .... B.t.u.
(61) Heat consumed per b.hp-hr. (Item 48 ÷ Item 57) .... B.t.u.

Efficiency Results

(62) Thermal efficiency referred to i.hp. (2547 ÷ Item 60) .. per cent
(63) Thermal efficiency referred to b.hp. (2547 ÷ Item 61) .. per cent

Specimen Diagrams

(64) Sample diagram each working cylinder ....

Electrical Data

(65) Average volts each phase .... volts
(66) Average amperes each phase .... amp.
(67) Total electrical output corrected for winding 1, 2 or 3 phase .. kva.
(68) Power factor .... per cent
(69) Total output in kilowatts .... kw.
(70) Field power .... kw.
(71) Net output in kilowatts .... kw.
(a) Field volts ....
(b) Field amperes ....

Power and Economy

(72) Electrical horsepower developed (Item 70 ÷ 0.7457) ....
(73) Fuel consumed per net kw-hr. Gaseous (Item 46 ÷ Item 70) . cu. ft.
Liquid (Item 53 ÷ Item 83) .... lb.
(74) Heat consumed per net kw-hr. (Item 48 ÷ Item 70) .... B.t.u.

TABLE 2 DATA AND RESULTS OF INTERNAL-COMBUSTION ENGINE TEST AT VARIABLE TORQUE AND SPEED

General Information

(1) Date of test ....
(2) Location ....
(3) Owner ....
(4) Builder ....
(5) Test conducted by ....
(6) Object of test ....

Description, Dimensions, etc.

(7) Type of engine, carburetor or oil, single- or double-acting, if four-cycle, the valve arrangement L, T, or I head, if two-cycle the type of scavenging, if single-acting, whether crosshead or trunk piston, if multi-cylinder, the cylinder and crank arrangement and if radial cylinders whether cylinders are fixed or rotate, and, means of fuel utilization by class name, such as Hvid, Diesel, or solid injection for example ....
(8) Class of service, aircraft, automobile, truck tractor, railroad or marine, for gear, electric or direct propeller drive, single direction or reversing ....
(9) Auxiliaries, attached and independent, kind, maker's name, capacity, etc ....
(10) Rated horsepower and speed, if any, or speed at maximum torque
(11) Bore and stroke of all working cylinders ....
(12) Weight of engine complete ....

		Run Number 1	2	3
(13) Brake horsepower	b.hp.	....	....	....
(14) Speed	r.p.m.	....	....	....
(15) Total fuel	lb.	....	....	....
(16) Time of run	hr.	....	....	....
(17) Fuel per hour	lb.	....	....	....
(18) Fuel per hour per b.hp	lb.	....	....	....
(19) Heating value of fuel .... B.t.u	lb.	....	....	....
(20) Heat consumed per hour (Item 17 × Item 19)	B.t.u.	....	....	....
(21) Heat consumed per hour, per b.hp. (Item 20 ÷ Item 13)	B.t.u.	....	....	....
(22) Thermal efficiency (2547 ÷ Item 21) ..	per cent	....	....	....
(23) Mean effective pressure equivalent to brake horsepower	lb. sq. in.	....	....	....
(24) Torque at one foot radius equivalent to brake horsepower	ft-lb.	....	....	....
(25) Fig. 1 Curve of r.p.m. plotted horizontal against vertical				
(a) Brake horsepower, Item 13		....	....	....
(b) Fuel per hour (Item 17)		....	....	....
(c) Fuel per hour per b.hp. (Item 18)		....	....	....
(d) Thermal efficiency (Item 22)		....	....	....
(e) Brake mean effective pressure (Item 23)		....	....	....
(f) Torque (Item 24)		....	....	....

Economic Features of the Machine-Tool Industry

(*Continued from page 153*)

times. That reserve is cost, not profit. If he does not have such a reserve he goes out of business by the bankruptcy route. An investigation showed that although they made a large part of the output, representative machine-tool companies did not earn quite 9 per cent on their investment for 10 years preceding the war. All of those earnings could not be taken out in cash dividends. Most of the earnings were reserves to carry over depressions.

Before the war, machine-tool prices were very low compared to the utility they gave their buyers. The prices advanced with the war, but advanced far less than prices of most war goods. The industry made money of course, but out of larger production, not out of excessive prices. The tax laws penalized the industry unjustly. The machine-tool builders financed their own expansion instead of asking the Government to do it. They now find themselves with expanded capacity that is much too large for any demand likely to arise in a few years. The prewar demand was largely foreign, and that is gone. Likewise the rapid growth of the automobile industry required many machine tools that have now been supplied. The second-hand market was glutted with all sorts of tools from dismantled war shops. All these factors combined to make the machine-tool business a very unhappy one for nearly three years.

As to remedies, the machine-tool builders have few choices. The first is, to design something new and revolutionary that will make a new market by obsolescence of old types. Naturally, this is not easy, and very few companies will be able to work out this plan.

The second is, by mergers and consolidations to reconcentrate the industry in fewer shops and reduce overhead in proportion. But the individualistic machine-tool builder prefers to be his own boss, and may do his best work as such.

The third choice is to take on some entirely different product along with machine tools, which involves establishing an entirely separate selling plan, connections, etc.—not an easy thing to do.

The fourth choice, for those who cannot for any reason take either of the other three, is to quit the field before bankruptcy closes the shop doors.

The machine-tool industry has an ethical standard—that simple one on which dependeth all the law and the profits, the Golden Rule. Through long years the leading machine-tool builders have built up their business on that standard. The violation of the Golden Rule by some of their customers cost them a lot of money in the deflation of the last boom.

Abuses became so audacious and common that the industry is now determined that the Golden Rule is good enough to work both ways. To protect the industry and its honorable, considerate customers, steps are being taken to make available to the industry full information regarding those who use unfair methods of various sorts. The responsible, reliable machine-tool builder will hereafter take an order to be a contract, not a buyer's option subject to cancellation. He believes in a price that is right all round, right for the customer, right for his own stockholders, for his employees, for his family, and for himself. He believes in the same price for all his customers, without the discriminatory shading here and there that only gives some shrewd buyers an inside edge on the fair ones who are willing to pay a right price.

As a result of the depression of 1921 and 1922 the wide-awake machine-tool builder is giving close attention to the economics of his industry and the nature of his demand. He is studying what to do and what not to do at various stages of his business cycle. He is contributing statistics whereby the stages of his cycle are disclosed. In his mind he is correlating his shop as a part of the industry, and his industry as a part of the big industrial machine that turns out goods of all kinds for the world's comfort. He realizes that his is one of the intermittent gears in the machine, and that as long as the other elements of the machine compel him to work so much more slowly at times, he must regulate his finances so as not to get caught in a squeeze. Such correlation will make a better industry with sounder, saner conditions than the machine-tool builder has ever known, either in booms or depressions.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Electrochemistry A1-23. A New Method for Determining the Rate of Sulphation of Storage-Battery Plates. Technologic Paper No. 225 of the Bureau of Standards, just issued, describes experiments which have been made to develop a speedy and accurate method for measuring the effect of impurities in storage-battery electrolyte. In the present paper the fundamental theory of the method and measurements of the rate of sulphation of the plates in the pure acid are given. An extension of the investigation is planned which will include the effect of added impurities following the method here described. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 5 cents.

Fluid Flow A1-23. Experiments in the Flow of Water in Vertical Tubes of Diverging Cross-Section. Messrs. R. H. Morris and A. J. Houston have recently completed a series of experiments on this subject at the Hydraulic Laboratory of the Massachusetts Institute of Technology. This research was a continuation of the one carried on a year or so previous under the direction of Prof. George E. Russell.

It was hoped to establish some relation between the length and angle of the tube, or the length and ratio of end areas, which would give the maximum discharge for a given head. The authors in their conclusions state that, while the data obtained are unsufficient to warrant the deduction of any general formula expressing the relation between angle and length of tube which would give the greatest discharge for a given head, it may be quite definitely said that, within the limits of the present investigation, for any given head, the longer the tube the greater the discharge and, for a given length of tube, the maximum discharge is obtained with a tube having an angle of between seven and ten degrees. They feel that there is a great field for further investigation along these lines.

One copy of this research is on file with the Librarian of the Engineering Societies Library, 29 West 39th Street, New York.

Fuel Utilization A1-23. Carbon Monoxide in the Products of Combustion from Natural-Gas Burners. Many gas appliances are notoriously inefficient. Solid-top stoves with low-set burners and grid-top stoves with low-set burners consume from two to eight times as much gas as stoves with raised burners and grid tops. On account of the liberation of carbon monoxide, a poisonous gas, with the products of combustion when the flame is improperly aerated, it is not practical to place burners at the distance from utensils where the maximum efficiency is obtained. Burners of the "star" type should be placed about one in., the "slot" burner about 3/4 in., and the "disk" type about 1 1/4 in. from the utensil.

From the many tests for carbon monoxide made with five different burners and different types of flames at rates of consumption of 6.0 and 8.0 cu. ft. per hour (6480 and 8640 B.t.u. per hour), the maximum rate of liberation of carbon monoxide was found to be 0.25 cu. ft. per hour and was obtained with a very soft flame and a close position of utensil which caused the flame to "float" and extend up the side of utensil. It is not a dangerous rate unless one works directly over the burner, or several burners are in use at the same time for several hours, or the room is unventilated.

No carbon monoxide was found where the blue inner cone of the flame was not allowed to touch the utensil. A yellow flame will produce carbon monoxide at a rate much greater than a blue flame when the utensil is so close to the burner as to cause a floating flame.

A natural-gas flame was found to be smothered from deficiency of oxygen when the content of the atmosphere had been diminished to about 15.5 per cent. When one considers the natural ventilation which takes place through the windows and doors it would seem that the danger from carbon monoxide poisoning with natural-gas top burners is quite remote.

This Technologic Paper No. 212 of the Bureau of Standards was prepared by Messrs. I. V. Brumbaugh and G. W. Jones and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

Fuel Utilization A2-23. Value of Coke, Anthracite, and Bituminous Coal for Generating Steam in a Low-Pressure Cast-Iron Boiler. Technical Paper No. 303 of the Bureau of Mines records the results of a series of tests conducted primarily for the purpose of determining the relative steaming values of coke, anthracite, and bituminous coal when burned in a low-pressure boiler, and fired by hand in fairly large quantities at a time.

A secondary purpose of the tests was to separate the heat losses, and to examine them carefully to determine the change in efficiency with the method of firing the fuel and manipulation of the draft dampers, with the rate of evaporation, and with the various fuels burned.

Address Superintendent of Documents, Government Printing Office, Washington, D. C., for a copy of this paper. Price per copy, 10 cents.

Fuel Utilization A3-23. Economic Combustion of Waste Fuels. Since its establishment the Bureau of Mines has conducted investigations relating to efficiency in the utilization of fuels, including the utilization of fuels of such low grade that they are in many places classed as waste. Because of the decreasing supply and increasing cost of high-grade fuels, the efficient utilization of those that are low-grade is becoming a problem of major importance to many industries and to the commercial progress of the nation. The data in this paper, consequently, are published as a contribution to the literature on the conservation of national resources.

This bulletin known as Technical Paper No. 279 was prepared by Mr. David Moffat Myers. It consists of 51 pages and may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Fuels A1-23. Economic Combustion of Waste Fuels. See *Fuel Utilization A3-23.*

Gases A1-23. Carbon Monoxide in the Products of Combustion from Natural-Gas Burners. See *Fuel Utilization A1-23.*

Gases A2-23. Fixation and Utilization of Nitrogen. This report has been prepared in order to correlate and make available under one cover such information on the fixation and utilization of nitrogen, collected by the Nitrate Division since its organization in July, 1917, as may aid in the further development of that art in the United States. It was prepared with the assistance of the Fixed Nitrogen Research Laboratory of the Department of Agriculture and is based to a very considerable extent on reports, papers and articles prepared by the officers and civilians associated from time to time with the activities of the Nitrate Division, as well as on the published technical and economic papers of several others. A bibliography of many of the papers pertaining thereto that have appeared in the last few years is included. Address Nitrate Division, Ordnance Office, War Department, Washington, D. C.

Lubricants A1-23. Reclamation of Used Petroleum Lubricating Oils. A series of tests recently completed by the Bureau of Standards' staff have demonstrated that used lubricating oils may be reclaimed by apparatus already commercially available and thus saved for further use. Such reclaimed oils will pass all the commonly accepted tests for new oils, such as flash point, viscosity, and sediment. This investigation is fully described in Technologic Paper No. 223 of the Bureau of Standards, for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. at 5 cents per copy.

Petroleum and Allied Substances A1-23. Reclamation of Used Petroleum Lubricating Oils. See *Lubricants A1-23.*

Radioactivity A1-23. Mesothorium. The chemistry of mesothorium, the radioactive element found in monazite sand and other thorium minerals, which is used as a substitute for radium in the manufacture of certain luminous paints and for medicinal purposes, is discussed in Technical Paper 265, just issued by the United States Bureau of Mines.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Building Materials B1-23. Fire Resistance of Hollow Building Tile. An investigation of the fire resistance and related physical properties of hollow building tile has been conducted by the Bureau of Standards during the past two years in coöperation with the Hollow Building Tile Association. A furnace, suitable for making fire tests of small panels up to 4 ft. square, was built and tests of unprotected panels built from tile of representative clays have been made in order to establish characteristic behavior under fire. A wide range in fire resistance was found, depending mainly on the mineral composition of the clays employed. As a possible means of increasing fire-resisting properties, grog additions up to 10 per cent were tried, but it was found that the small addition which can be conveniently made in manufacturing practice had no effect, and that additions of 5 per cent or more decreased the fire resistance. The protection afforded by typical plasters has been determined, obtaining, generally excellent results.

The effect of the addition of combustible filler to the raw material, of the fineness of grinding of the raw material, of the size of the unit, and of changes in design of the tile, will be ascertained. Address the Director of Bureau of Standards, Washington, D. C.

Fire Prevention B1-23. FIRE RESISTANCE OF HOLLOW BUILDING TILE. See *Building Materials B1-23.*

Electrical Instruments B1-23. ELECTRIC TELEMETER. During the past two years or more the Bureau of Standards has been engaged in developing electric telemetric devices based upon the fact that carbon contact resistances vary with pressures or displacements applied to their terminals. In the past there have been several inherent difficulties with apparatus of this kind. The Bureau has investigated all of these sources of trouble and has found means of eliminating all of them to a degree which makes the apparatus well adapted to a great variety of engineering measurements.

These measurements include those of strains in bridge members and other engineering structures, of accelerations, vibrations, and pressures of practically every description. The apparatus can be made either indicating or recording as desired. Up to the present time both indicating and recording instruments embodying this principle have been made for and largely used by the Bureau of Aeronautics of the Navy Department for measuring stresses both in airplane members and dirigibles where it is very important to read such stresses at a point more or less remote from the member under test. Similar apparatus has also been used extensively by the Bureau of Standards in laboratory tests on large structural members and also in connection with certain dynamometer work, and for much of this work the new instruments have been found to be substantially equal in accuracy to anything heretofore available in the line of indicating instruments, and they possess the additional advantage of permitting remote reading as well as graphic records to be made when desirable. Work is now in progress on the extension of the field of application of these instruments to various lines of engineering work to which they are adapted.

Instruments and Apparatus B1-23. ELECTRIC TELEMETER. See *Electrical Instruments B1-23.*

F—BIBLIOGRAPHIES

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E These bibliographies are on file at the headquarters of the Society.

Electricity, General F1-23. ELECTRICAL INSULATING MATERIAL. In connection with the Bureau's investigation of the properties of certain types of electrical insulating materials, a rather comprehensive bibliography of papers, books, patents, and periodicals has been prepared.

Since a considerable demand has arisen for copies of these, they have been issued in mimeographed form as Letter Circulars Nos. 50 and 51 "Bibliography of books and titles of periodicals on properties and uses of insulating materials" and "Lists of the more important U. S. patents covering the materials and methods of manufacture of an insulating material." Only a limited supply of these two letter circulars is available, but a copy will be sent on request, as long as the supply lasts, to any person who can show an actual need for them. Address the Director, Bureau of Standards, Washington, D. C.

Gases F2-23. FIXATION AND UTILIZATION OF NITROGEN. An eleven-page bibliography on this subject forms an appendix to Report No. 2041 of the Nitrate Division of the War Department just issued. It contains references to material published from 1917 to the present.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Surge-Tank Problem

IN DISCUSSING a paper on surge tanks by Professor Durand[1] which appeared in the October, 1921, issue of MECHANICAL ENGINEERING (p. 643), R. D. Johnson,[2] in a letter published in a later issue (August, 1922, p. 541) stated that a differential surge tank *without exception* is cheaper than a simple surge tank for fulfilling the same conditions. This statement was challenged by B. F. Jakobsen[3] in a communication printed in MECHANICAL ENGINEERING, November, 1922, p. 764, and further in the closure to the discussion of his paper on surge tanks before the American Society of Civil Engineers. The paper in question is mainly devoted to a general consideration of the problem of surge-tank action in the Kerckhoff plant of the San Joaquin Light and Power Corporation. Special reference is made to the design and tests of the Kerckhoff surge tank, a simple cone-shaped tank 17 ft. in diameter at the top and 39.5 ft. at the bottom.

In his closure Mr. Jakobsen states that the Larner-Johnson Valve and Engineering Co. was asked to furnish a design of a differential surge tank and accordingly submitted one consisting of two independent shafts, one 7 ft. in diameter rising directly above the tunnel, and the other 20 ft. in diameter offset from the tunnel and connected at the bottom to the tunnel and at the top to the riser. This design was not adopted because it would have been as expensive to excavate as the simple surge tank, and also for the following reasons:

"This differential surge tank would permit an increase from no load to full load in 3 min., as will also the Kerckhoff surge tank. For such a load increase, this tank is comparable with the Kerckhoff tank. However, when the load is increased instantaneously, or within a few seconds, from 1000 to 1500 sec-ft. (1500 sec-ft. being about full load on the plant), the water surface in the differential surge tank is decreased from Elevation 965 to Elevation 932, or the head on the plant is reduced by 33 ft. (about 10 per cent of the total head) in 10 sec.; whereas in the Kerckhoff surge tank the decrease in head is only 8 ft. in 10 sec. Both surge tanks meet the condition imposed on them, but during the first minute after the turbine gates have opened, the plant with the Kerchkoff surge tank supplies on an average nearly 2000 kw. more than the one with the differential surge tank, and 10 sec. after the moment of regulation the Kerckhoff surge tank supplies about 2700 kw. more than the differential surge tank. As this is nearly the ultimate capacity of the plant and for nearly full gate and at a time when every kilowatt counts, it is an advantage in favor of the Kerckhoff surge tank. The normal full load on the Kerckhoff plant is 35,000 kw., although 40,000 kw. have been generated for several hours when the tail-race elevation was relatively low."

Denying the statement of R. D. Johnson that the differential principle produces without exception a cheaper tank, Mr. Jakobsen believes that "the differential surge tank has its advantages, but it is not always the best possible type, as is shown by the previous discussion. Each plant requires a special study, and the size and shape of the tank depend on the conditions to be met and the physical constants of the plant. The success of the design depends also largely on the designer's ability to appreciate properly the operating conditions which will be imposed on the plant."

The dispute between Mr. Jakobsen and the advocates of the differential surge-tank principle resolves itself, therefore, not to the question as to whether the differential surge tank has its advantages over the simple type under conditions favorable to the former, but whether there can be any conditions under which the simple tank might be preferred, and, in particular, whether the conditions at the Kerckhoff project were such as to warrant the use of the differential surge tank in preference to the simple surge tank.

The editors have recived a number of letters advocating the differential-tank principle, but because of lack of space it is impossible to reproduce all of them, notwithstanding their interest. It has

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[2] Hydraulic Engr., New York, N. Y. Mem. Am Soc M.E.
[3] Construction, Hydraulic and Electrical Engr , Fresno, Cal

been decided, therefore, to publish in full a communication received from Mr. Johnson, the earliest champion of the cause of the differential surge tank, and to give extracts from the other letters. It is believed that this will serve to bring out the salient points of the discussion.

R. D. Johnson's Letter of November 29

To the Editor:

With further reference to my letter on the subject of Surge Tanks, appearing in your December number, I now have in hand a reprint of Mr. Jackobsen's closure of his A.S.C.E. paper to which he referred in your November issue and therefore I can answer his statements with a little more idea of what he is driving at.

He shows two surge diagrams, one for a small differential surge tank and one for a larger conical simple tank, which have the same amplitude of surge for a given instantaneous load change.

The load on the plant previous to the instantaneous load demand is the same in both cases and is proportional to the product of 1000 c.f.s. and a head represented by elevation 964 at the tank. The load change, he says, is such as to practically reach the limit of the capacity of the turbines, when discharging 1500 c.f.s. at the lessened head (equal in the two cases) which exists at the lowest point of the surge shown as Elevation 932. These two cases are therefore equivalent, if the computations are correct, and serve in no way to prove his contention of a "distinct disadvantage." There is obviously no shortage of power of 2000 or 2700 kw. or any other amount and it was some time before I could guess where he got this idea, but it appears that he has figured a hypothetical shortage proportional to the difference of head, in the two cases, at precisely the same time abscissas, which, of course, has no practical bearing on the case

It seems superfluous to point out that power output is made up of two factors, one of which is the head on which Mr. Jakobsen bases his conclusions and the other, which he does not take into account, is the varying discharge of the turbines during a surge due to the action of the governor in its effort to maintain at constant value the additional load which has been assumed to be suddenly demanded in the beginning.

The governor is capable of moving at a far greater rate of speed than is required to follow up the drop of water level either in a simple tank or in a differential regulator of proper design with adequate area of riser. The sudden accession of load is therefore adhered to in either case, if the governor is any good.

If he has inadvertently assumed a constant discharge of the turbines during the surge, thus making it possible to claim a shortage in power output proportional to a difference in head (at the same time abscissas in the two cases), he is then subverting the facts in substantiation of a claim which has no bearing on the practical operation of a power plant.

Some light on his method of figuring surges may be gleaned from a glance at his Fig. 9. This purports to be a surge diagram following a gradual increase in load from 9,000 to 27,850 kw. in 70 sec., after which, during the remaining minutes shown in the figure, the load is supposed to be maintained constant. At least, he gives the same figure for it when the water quiets down at Elevation 970.2.

While this is quite possible with a varying discharge through the turbines, it stretches the imagination to understand how the load can remain constant with a constant discharge of 1145 c.f.s. while, at the same time, the head is varying from elevation 954.1 to elevation 982.3, which variation, with a constant discharge of the turbines, would amount to as much as 3000 hp. to say nothing about the magic invoked to keep the discharge constant. An explanation of this is desirable.

This little study may furnish an index to his process of thought and may account for his views in regard to a shortage of power, due to differential action.

The two equivalent tanks which he illustrates differ in volume and they could only be considered to cost the same, as he says they do, by using a larger unit price on the extra shaft for the riser; but it is well known that the riser may just as well be placed within the tank, by adding its volume to the single excavation, or it might be run up on the outside slope of the hill, if the topography is suitable for such a course.

This particular sketch, I find upon inquiry, is a study which passed out of the office of the Larner-Johnson Valve and Engineering Company in the course of correspondence, setting forth arguments in favor of the differential regulator, and it never had any such final consideration as is always given to a design, favorably received, where there seems to be a desire to go thoroughly into the matter, looking toward its adoption.

Fortunately, it seems to be about all right, on casual inspection, except that neither this regulator with its small riser nor his own surge tank would be considered adequate for the usual requirements with which we are familiar, especially for low or medium-high heads.

Frequently such plants are fed by wood-stave pipe lines regulated by steel tanks built on high towers, where spilling large rates of flow at a high elevation is economically out of the question and where every foot of surge both upward and downward is a matter of importance. These are the very cases for which Mr. Jakobsen promised, at least by implication, to set forth in his advertised article, something better than the differential regulator and many will be disappointed to find nothing in support of his assertions.

The surge in the Kerckhoff tank, shown in Fig. 16 (Wahlman's discussion of Jakobsen's paper), does not take into account the augmenting effect of governor action, and inasmuch as this is the only thing which works against the friction of the conduit to increase and keep alive fluctuations in water level, it will probably be clear to those familiar with these questions that the surges as shown would be much amplified if the customary governing action was to be imposed upon them.

Even here it will be seen that the water level returns, upon the first recoil, to an elevation slightly greater than that at which it started, although no load has meantime been rejected. This condition would of course be worse with a governor trying to hold the power output at constant value.

When a power plant is supposed, at times, to stand upon its own feet in respect to regulation and not therefore always able to shift some of its responsibility to other plants in parallel, which may be better equipped for the purpose, it is not considered good practice to permit much instability in the water level.

In Mr. Jakobsen's closing words, he distinctly leaves it to be inferred that rapid damping of oscillations is due to the conical shape of a surge tank.

With the use of a simple tank of whatever shape there is only one thing that tends rapidly to kill surges, and that is excessive friction in the conduit.

In the case cited, very rapid damping of oscillations would be taken as an indication that an unwarranted amount of useful head was being wasted in the conduit.

With a simple tank, rapid damping, so essential, if often very expensive; it is not a function of the conical shape and, furthermore, Mr. Jakobsen's example does not indicate rapid damping.

With differential action, however, the rate of damping is increased without the loss of useful head on the turbines.

In closing, I wish again to refer to the words of mine, which Mr. Jakobsen quoted at the beginning of his letter, viz: "It is difficult for the writer to find any excuse for omitting the differential principle when its use, without exception, produces a cheaper surge tank, which will fulfill the same conditions."

It must be understood that this is merely a rule and possibly subject to the inaccuracy of all rules which are said to require an exception to prove them. However, in running through my mind some two score surge-tank designs with which I am familiar, I am able to state that the ratio of cost of the simple tank to the differential varies greatly with the physical conditions; it has rarely been found higher than 3, not infrequently as high as 2, commonly as high as 1.75, sometimes lower, but never, up to date, nearly as low as unity.

The ratios seem to be larger for structural tanks than for excavated ones and it is probably in that field, if anywhere, that an exception might be found.

Perhaps someone will feel enough interest in the matter to ferret out and publish the exception which is now lacking for a thorough establishment of the rule and then its acceptance might possibly be made universal.

New York, N. Y. R. D. Johnson.

In a letter dated November 27, Norman R. Gibson[4] questions whether Mr. Jakobsen's conclusions were based upon a comparison of the actual performance of representative surge tanks of both types and adds that it is obvious that not all surge-tank designs are correct, nor any one design of any type suitable for all conditions.

T. H. Hogg[5] in a letter dated November 21 points out that "the differential tank acceleration is faster than that of the simple tank, due to the greater drop in the water surface in the riser of the differential tank during the early part of the first quarter cycle, which results in a lower operating head on the turbine. If sufficient flywheel is provided to prevent an undue change of speed during the initial movement of the governor this condition does not give less power during the period than would result from the action of a simple tank, because the greater acceleration in the conduit, together with the capacity of the riser itself, more than compensates for the additional decrease in head, and as a result more power is available during this period with the differential tank than with the simple tank. Since the water level in the simple tank at the end of the first quarter-cycle is lower than in the differential tank, a greater amount of water is required by the turbine to meet the power demand, and, therefore, the gate opening on the turbine and hence the work done by the governor must be greater than for a differential tank.

"While the drop in the water level in the riser of the differential tank is more rapid than in the simple tank, it requires considerably greater time to reach its low level than the time necessary for the governor to make a full-gate stroke, and it is quite evident that with a governor set to take care of a given load change in a reasonable time, with constant head, it is perfectly capable of taking care of the same change with the slight and comparatively gradual change which occurs in the riser during the interval."

F. J. Howes[6] (letter dated November 13) states that "a thorough discussion of the relative merits of simple and differential surge tanks is made so difficult by the vast amount of arithmetical integration required that a proper sense of proportion is likely to be lost. The writer had occasion not long ago to compare the dimensions of both types of tank which would be required to give equivalent speed regulation on a station of 33,000-kw. capacity on a head of 130 ft. The results from a differential tank 52 ft. in diameter had as good commercial characteristics as could have been obtained from a simple tank 90 ft. in diameter, in spite of the extreme drop in head occurring on the occasion of a sudden demand."

Eugene E. Halmos[7] (letter dated November 16) says that from his experience the differential surge tank results in considerable economy in first cost where a fixed maximum or minimum head on the conduit or penstocks is of importance. He adds, however, that it is just conceivable that where the surge tank is an unlined excavated hole in solid rock, the cost of additional excavation to obtain the diameter necessary for an equivalent simple tank might balance the cost of the riser of the differential tank.

Lewis F. Moody[8] in his letter of December 2, 1922, formulates the broad problem of surge-tank functions, which is to handle in the best possible manner the oscillations which must inevitably occur as the result of the inertia of the water column. The engineer has first to limit the magnitude of the disturbance, and second, to provide for damping it out. Mr. Moody believes that the simple surge tank will accomplish the object of limiting the amplitude of the oscillations if the tank is sufficiently large. Unless relatively very large in dimensions a simple tank will not accomplish the second purpose of damping out the surges, and, in any event, it is not the tank which produces the damping but the friction in the hydraulic conduit. In his opinion, therefore, the so-called simple surge tank is a *surge* tank indeed, since it provides for a continuance of the periodic fluctuations until these are absorbed by friction in the pipe line. If the simple surge tank is not as large as it should be—and this is often the case—it may cause perpetual surging or even augmenting surges.

C. W. Larner[9] (letter dated December 4) objects to Mr. Jakobsen's assumption that an instantaneous load change requires an increase of plant discharge from 1000 c.f.s. to 1500 c.f.s. in a few seconds, and to the further assumption that the 1500 c.f.s. discharge is to be constant in spite of the fact that the head on the plant begins to fall off immediately due to the downward surge in the tank. He believes that such a load increment could not possibly occur in practical operation. This condition is illustrated by a curve in the letter.

Objection is also made to Mr. Jakobsen's alleged argument that the differential tank is not as good as the simple because at each instant during the early part of the surge, the head in the differential tank is lower and the power output less. The writer claims that both surges are identical if we eliminate the element of time. Both start at the same elevation and both end at the same elevation. For every point on the differential-tank curve there is a corresponding point on that of the simple tank. The only difference is that one occurs later than the other.

Mr. Larner suggests that load change be expressed in kilowatts instead of cubic feet per second. He further suggests as the only proper hypothesis for design or comparison of designs, the facts that the discharge of the wheels during the surge will vary and the gates will not be wide open until the bottom of the surge is actually reached. Hence, while it is clear that earlier in the surge the plant could turn a little more power if the gates were opened wider, he does not attach any importance to this because this additional power would have to be dropped a few seconds later.

Minton W. Warren[10] (letter dated December 20) states that if the matters of first cost and interest on the investment are left out, Mr. Jakobsen's statements as to the superiority of the simple surge tank over the differential for the Kerckhoff project are certainly true. He points out that the differential tank is rapidly becoming standard practice and states his belief that in cases where labor, material, and physical conditions are such as are found in the medium-high-head plant in the United States, the differential principle utilized in some form will be found to be an advantage.

Fred W. Ely[11] (letter dated January 31, 1923) in analyzing the reasons which led Mr. Jakobsen to reject the differential surge tank, states that while it is true that during the first 60 sec. the differential tank gives an average of nearly 2000 kw. less than the simple tank, in the next 97 sec. the level in the simple tank is still slowly flowing while that in the differential tank is rising, and therefore the power lost in the first quarter-cycle is gained in the second. The writer believes that the flywheel effect of the rotating machinery could be relied upon to tide over the period during which the short water column in the penstocks is accelerating. Moreover he believes that actually no deficiency of power exists at any time under operating conditions involving constant power; the above is simply predicted on Mr. Jakobsen's condition of constant discharge which the writer claims is impossible. Furthermore, the final quiescent level for the changed conditions will be attained in the differential tank in about one-half the time this level is reached in the simple tank.

While the discussion has been primarily devoted to the argument as to whether, in the face of developments of the differential surge tank, there are any contingencies still left in which a simple tank would be preferable, it has brought out in passing some interesting suggestions as to the problem of surge-tank design to meet special conditions. Thus, Mr. Ely, in his letter referred to above, discusses the case of a tank extending some distance above the ground, where excessive spilling in most cases is impracticable. One plant with which he has had some experience—the Colton Plant of the St. Lawrence Transmission Company at Potsdam, N. Y.—required a tank extending 250 ft. above the ground. A simple tank in such a location would be out of the question, even though this plant falls within the scope of Mr. Jakobsen's classification of low- and medium-head plants. The differential surge tank on this development has furnished satisfactory regulation with no indication of a deficiency of power or fall in speed on suddenly demanded loads.

Letters have also been received from Messrs. P. Wahlman and O. V. Kreuse, but cannot be quoted here because of the lack of space.

[4] Cons. Engr., Niagara Falls, N Y.
[5] Eng Dept., Hydro-Electric Power Commission of Ontario.
[6] Rochester Gas & Elec. Corp., Rochester, N. Y.
[7] Civil Engr., New York, N. Y.
[8] Asst. to Vice-Pres., Wm. Cramp & Sons, Ship & Engine Builders, Philadelphia, Pa. Mem. Am.Soc.M.E.
[9] Pres., The Larner Engrg. Co., Philadelphia, Pa.
[10] Eng. Dept., Kalmus, Comstock & Westcott, Inc., Boston, Mass.
[11] Engr. Aluminum Co. of America, Pittsburgh, Pa.

Variations in Design of Milling Cutters

(*Continued from page 158*)

metal, and energy required per chip on rise in temperature. Aside from this condition and in the case of work where the wide spacing of teeth would cause undue hammering, coarse-tooth cutters should always be used.

Effect of Spiral Angle and of Rake Angle

A large number of runs were made on a set of three 10-tooth cutters having spiral angles of 10, 20 and 30 deg., respectively, and on two 20-tooth cutters having spiral angles, respectively, of 20 and 30 deg. In addition two series of tests with a three-tooth 60-deg. spiral cutter are shown in Figs. 1 and 2. As noted earlier in the report, the metal used in the tests of the first five cutters mentioned was not uniform, so no definite figures are given. The average of the tests, however, shows practically no difference in power required for the different spiral angles. In the case of the three-tooth cutter the authors believe that the lower power requirement is due to the number of teeth instead of the spiral angle.

While increased spiral angles showed no advantage from the standpoint of power, they were of very great benefit in reducing tendency to chatter and in giving smoother action. The vertical pressure between cutter and work was also somewhat less. The end thrust with the 60-deg. spiral cutter was not noticeable as far as the machine was concerned. In general a considerable spiral angle is desirable, the only limitations being end thrust and the danger of burning the sharp corners at the ends of the teeth if the work extends beyond the end of the cutter.

Tests were made with three 10-tooth cutters having rake angles of 0, 10, and 20 deg. and with two 20-tooth cutters having 0 and 10 deg. rake. The increase in rake angle from 0 to 10 deg. caused a saving in power of 20 to 25 per cent, and a somewhat smaller saving was shown on the increase to 20 deg. On the other hand, tendency to chatter increased only slightly between 0 and 10 deg. rake, but became so great as to definitely limit the capacity of the cutter when increased to 20 deg. This limitation seemed to be much more serious than the danger of burning or chipping the edge. Rake angles of 10 deg., therefore, are desirable on cutters, but any considerable increase beyond this point limits the usefulness of the cutter.

Chatter

Chatter rather than the power of the machine is often the limiting factor in milling. For this reason many engineers urge that more rigid machines be built to eliminate this trouble, without realizing that a great deal may be accomplished by the proper choice of cutters. A summary of the elements which affected chatter in these tests is therefore given in the following paragraph.

The most important point in connection with this subject is the fact that tendency to chatter was greatly reduced as the number of teeth in the cutter approached a low figure. On many cuts where it was impossible to eliminate chattering of the twenty-tooth cutter by any reasonable change in speed, absolutely no trouble was experienced with the four- or eight-tooth cutters. Furthermore some trouble was experienced with the eight-tooth cutter on wide and deep cuts at high feeds, but no chattering occurred on any cuts with the four-tooth. Increase in spiral angle also reduces the tendency to chatter, and a combination of wide-spaced teeth and steep spiral angle in a cutter will give the maximum capacity along this line. Moderate rake angles increase the tendency to chatter but little, while large rake angles greatly decrease the capacity of the cutter. The proper consideration of these factors in the choice of cutters will eliminate much trouble in this respect.

Conclusions

Coarse-tooth milling cutters require less power to remove a given amount of metal per minute than fine-tooth cutters. This is true on both wide and narrow work, although the margin in favor of the coarse-tooth cutter is greater on wide cuts. It is also true if both cutters are compared on a chipper-tooth basis.

When compared on a chipper-tooth basis the finish given by the coarse-tooth cutter is better than that by the fine-tooth cutter on account of the closer spacing of revolution marks.

Low-cutting-speed operation of fine-tooth cutters to give a large feed per tooth is objectionable on account of the increased stresses in the machine and holding fixtures.

Fine-tooth cutters are much inferior to coarse-tooth cutters when the relative tendency to chatter is considered.

Moderate rake angles reduce the power consumption and are desirable on all cutters to be used on mild steel. Large rake angles are undesirable due to the tendency to chatter.

The spiral angle has little effect on the power consumption. A considerable spiral angle is desirable, however, because it makes possible the use of fewer teeth, gives smoother cutter action, and reduces the tendency to chatter.

Hence, with the few exceptions noted, coarse-tooth cutters of the type now generally manufactured are superior to fine-tooth cutters for all classes of production work.

U. E. S. Report for 1922

The report[1] of the treasurer of United Engineering Society for the calendar year 1922 shows a balancing account on December 31, 1922, of $17,014.77, as compared with a balancing account on December 31, 1921, of $26,434.31. The cash on hand as of December 31, 1922, amounted to $138,294.27. Following is a statement of the treasurer's receipts and payments for the year:

RECEIPTS

Cash on hand January 1, 1922		$14,219.35
From Founders and Associates	$138,294.27	
From societies not in building	17,811.17	
From various accounts	41,994.08	
From Library Service Bureau Photo Department	5,515.06	
From Library Service Bureau Search Department	9,274.28	212,888.86
		$227,108.21

PAYMENTS

For Operating Payroll	$46,919.31	
For Operating Expenses	37,225.22	
For Equipment, Repairs and Alterations	10,195.56	
For Miscellaneous, Including Taxes	53,144.50	
For Library	56,868.73	$204,353.32
Cash on hand January 1, 1923		$ 22,754.89

SUMMARY OF FUNDS, DECEMBER 31, 1922

Depreciation and Renewal fund	$133,233.69
General Reserve fund	10,000.00
Library Endowment fund	93,357.40
Engineering Foundation fund	502,074.80
John Fritz Medal fund	3,500.00
Total	$742,165.89

The assets and liabilities as of December 31, 1922, were as follows:

ASSETS

Property		$1,959,140.67
Land	540,000.00	
Building	1,361,969.51	
Equipment	33,171.16	
Founders' Preliminary Expenses	24,000.00	
Investments—Engineering Foundation		502,074.80
Library		93,357.40
Depreciation and Renewal		133,233.69
General Reserve		10,000.00
Operating Cash	13,350.01	
Library Petty Cash	50.00	
Accounts Receivable	3,869.65	17,269.66
		$2,715,076.22

LIABILITIES

Founders Equity in Property		$1,959,140.67
Engineering Foundation Fund		502,074.80
Library Endowment Fund		93,357.40
Depreciation and Renewal Fund		133,233.69
General Reserve Fund		10,000.00
Deferred Credits-Unexpended balance in International Dinner Fund	$ 54.89	
Library Income for year 1923	200.00	254.89
Balance in Activity Accounts		17,014.77
		$2,715,076.22

[1] Extracts from treasurer's report for 1922.

MECHANICAL ENGINEERING

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Overdeveloped Coal Industry Cannot Furnish Cheap, Plentiful Coal

THAT the coal industry is overdeveloped is an outstanding definite statement in the first report of the United States Coal Commission. This overdevelopment has been common knowledge for some time, but its authoritative statement by the Commission should focus the attention of the public upon the high prices, faulty transportation, and unsatisfactory labor conditions that have resulted from an excess of two hundred thousand miners and a mining capacity of eight hundred million tons per year, when the annual consumption has never been greater than five hundred and seventy-nine million tons.

The final paragraphs of the report furnish an interesting commentary on this overdevelopment. Quoting from the report:

The way in which to reduce the overdevelopment of the mining industry is fraught with so many complications, not all of which are evident at first glance, that the Commission has not yet had time to ascertain sufficient facts on which to base any recommendations now to be made to the Congress. While it might be expected that in an overdeveloped industry aggressive competition would have driven out mines with high producing costs and forced prices to the consumer down to a minimum, so many such complex factors have operated to prevent the free play of economic forces that a very detailed and comprehensive investigation is required before a valid conclusion can be reached.

The inquiry involves the whole question as to what is best for the people, free competition, government or private ownership, regulation or control in the coal industry. Should the operators in given areas be permitted to combine so that the low-cost mines would furnish the product to the people and the high-cost mines be kept in abeyance to meet an emergency, properly regulated as to price and profit by some governmental agency, or should this prime necessity of life and business be left wholly to open competition in the market? This problem is of so great moment, with reference not only to theories of government but also to the economic life of the Republic, that the view of the Commission must be left to its final report.

The Commission believes that the public interest in coal raises fundamental questions of the relation of this industry to the nation and of the degree to which private right must yield to public welfare. It may be that both private property in an exhaustible resource and labor in a public-service industry must submit to certain modifications of their private rights, receiving in return certain guarantees and privileges not accorded to purely private business or persons in private employ.

In the absence of facts the Commission refrains from comment as to the effect of profiteering, labor difficulties, transportation deficiency, and lack of storage upon high coal prices and unsatisfactory supply. The Report clearly shows the gravity of these problems, however, and points out the many troublesome phases of each which must be investigated before the final report of the Commission can be written. Following is an abstract of the Report which was made public on January 15 and was signed by the entire Commission.

The coal problem begins with a contradiction. Yet, with resources of coal in the ground adequate for the needs of perhaps a hundred generations of Americans, the nation's coal bin is too often depleted and too often the prices paid for coal are much higher than seem warranted by the wealth of coal available. While it is true that a large majority of the states have coal mines within their limits, it is significant that all the anthracite comes from a narrow area of 480 square miles in eastern Pennsylvania and 93 per cent of the bituminous coal comes from three major areas: the Appalachian region, extending from Pennsylvania to Alabama, the greatest storehouse of high-rank coal in the world; the Eastern Interior region, comprising Illinois, Indiana, and Western Kentucky; and the Western Interior region, extending from Iowa to Arkansas and Oklahoma.

The coal-mining industry, in point of numbers employed, outranks any single manufacturing industry and stands next to transportation and agriculture. Approximately three-quarters of a million men are employed in this industry, of whom 90 per cent work underground. The capital invested, according to the rough figures of the census, is $2,330,000,000, of which $430,000,000 is invested in the anthracite region and the remainder in the bituminous fields. There are only 174 producers of anthracite and eight of these control over 70 per cent of the annual output, while there are at least 6000 commercial producers of soft coal, to say nothing of thousands of wagon mines and country coal banks. These producers operate 9000 commercial mines.

The bituminous output is consumed approximately in the following percentages: Railroads, 28; Industrials, 25; Coking, 15; Domestic, 10; Iron and Steel, 7; Public Utilities, 7; Export, 4; Mines, 2; Bunkers, 2. The coal industry does not end at the mines. Some 180 railroads take the coal at the mine mouth and transport it to thousands of destinations. Because the railroads are the largest customers of the bituminous industry, and because coal—anthracite and bituminous—constitutes one-third of the railroad's freight, the problems of the two are closely interwoven and their interests interdependent.

Nor does the coal industry end with transportation. To connect the thousands of producers, big and little, with more than 90,000 buyers of carload-lot coal scattered over 48 states, requires a widespread system of wholesale marketing. There are some hundreds of large wholesalers and a much greater number, perhaps 3500 in all, of smaller middlemen. Like the business of running mines, the business of selling has its problems and, like mining, it has also its abuses. The final link in the chain of coal supply is the retailer, who receives coal in carload lots from car or yard storage and delivers it in smaller quantities to the consumer. There are some 38,000 retail coal dealers, most of them conducting a small business. They handle about 130,000,000 tons of coal, or 14 per cent of the bituminous and two-thirds of the anthracite produced. Combined charges of the railroads, the wholesaler, and the retailer in most localities exceed the price of the coal at the mines. Therefore it is readily seen that the problem whether the transportation and marketing charges are just and fair is of the utmost concern to the consumers of coal.

It has been suggested to us that one of the causes of high prices of coal is profiteering. There has been profiteering in the sense that grossly exorbitant profits have been taken at times by many operators, brokers, and retailers; profits that have been disproportionate to the cost of the coal or the service rendered or the risk incurred. But this Commission has not obtained the figures for the past ten-year period specifically required by the Act in order to settle this question.

There can be no doubt that two of the three periods of high prices since 1916 have been caused largely by labor troubles. In the first period of scarcity—August, 1916, to March, 1918—there were no strikes of consequence and therefore some other explanation of the high prices and distress must be found. The second period of runaway prices, November, 1919, to late in 1920, was originally caused by a nation-wide strike of miners beginning November 1, 1919. In this case the shortage created by the strike was aggravated by difficulties in transportation resulting in part from severe weather and in part from a strike of railway switchmen, and was further intensified by an unprecendented demand for export and by boom times at home. In the third period of shortage and high prices, from which we have not yet emerged, the primary cause was a nation-wide suspension of mining, involving practically all union men, which closed the anthracite region completely and shut down two-thirds of the capacity in the bituminous fields of the United States and Canada.

An opinion commonly expressed before the Commission is that the primary cause of scarcity and high prices of coal is transportation deficiency. There have been recurring periods of "car shortage," and such periods have generally been accompanied by high prices of coal. There are many other causes for the inadequacy of transportation beside the absence of cars, such as lack of motive power, congestion of yards, terminal facilities, or gateways, single tracks where double tracks are needed, inability to coördinate movement of boats and cars at ports, strikes of railway labor, and severe winter storms temporarily blockading traffic. The so-called "car shortage" is not always due to insufficient coal-carrying equipment alone. In part it has been due to an overload upon the transportation system beyond what that system could reasonably or properly be expected to bear.

We find that in the bituminous industry since 1890 the mines have averaged over the country as a whole, only 213 days out of a possible working year of 308 days. These averages, of course, show nothing as to the relative annual earnings of individual miners or their individual opportunity to work. In 1920, a year of active demand, the average time worked was only 220 days,

and in 1921, the year of depression, it dropped to 149 days, with many districts showing a figure much below this average. Over a long period comparatively little of the time lost has been on account of strikes and that in the years when there are no strikes the aggregate time lost from all causes is about as great as in those when strikes occur. In the twenty-three years over which the statistical record of strikes extends, the time lost because of strikes has averaged 9 days a year, or less than 10 per cent of the time lost for all causes combined. Short working time is the result of overdevelopment in the industry. There are more mines and more miners than the needs of the country require.

Although the country has never been able to absorb in a year more than 579,000 000 tons of bituminous coal, the present capacity of the mines is well above 800,000,000 tons.

The steady increase in the army of bituminous coal miners during the last four years, notwithstanding a lessened demand for their product is also a fact that stands out in the statistical records furnished the Commission by the U. S. Geological Survey. In 1918, the year of maximum coal output, when 579,000,000 tons were mined, 615,000 men were employed in the bituminous coal mines, nearly 622,000 the next year, over 639,000 in 1920, and in 1921, 663,000 mine workers were employed in producing about 416,000,000 tons. To get a year comparable in soft-coal output with 1921 we have to go back to 1910, when 417,000,000 tons were mined, and it is significant that in that year less than 556,000 mine workers were employed—or about a million more tons of coal with 100,000 fewer miners.

The Commission is convinced that there can be no permanent peace in the industry until this underlying cause of instability is removed. Diverse causes have apparently promoted overdevelopment and inquiries are in progress as to the relative importance, among others, of the following: The policy of railroads toward encouraging the opening of new mines and new mine fields as sources of revenue; car distribution rules that permit, if they do not encourage, larger capacity than the market obviously requires; the opening of new mines by large consumers; the establishment of freight rates that encourage the development of new fields; shifts in centers of consumption that abandon old fields and encourage new fields; the difference between union and non-union wage costs; large-scale suspensions in the unionized fields; and irregularity of demand.

American Railroads

THE PROBLEMS of our American railroads should be considered with two thoughts clearly in mind, both of them of intimate relation to American industry and engineering generally. First, our railroad system is the fundamental in a national scheme of production and distribution; and second, the railroad industry with an investment conservatively estimated at twenty billion dollars, has an annual purchasing power, when in healthy condition, of over a billion dollars. The factors that impair this purchasing power immediately reduce industrial activity.

The relation between transportation—and in particular, railroad transportation—and production was effectively discussed by Julius H. Barnes, president of the Chamber of Commerce of the United States, before the American Society of Civil Engineers at its recent annual meeting. While Mr. Barnes considered motor-truck and water transportation, he was careful to emphasize that our railroads remain always the chief channel of transportation. He was not able to give definite figures, but he did point out that the ultimate effect of the increasing ability of the individual to produce, his increasing buying power and his ever-widening demand for goods will result in the not-far-distant future in the serious embarassment of our transportation scheme. While the railroads have, during the past two decades, kept step with the increased transportation needs of the country, Mr. Barnes called attention to the fact that any material expansion of transportation service must require large additional capital investments. It is probable that some single- and even double-track lines are approaching the maximum load possible for the capacity of their present rails, and any substantial increase means at once new roadbeds. The service limit of existing terminal facilities is even nearer to the maximum possible, largely because not enough money has been spent on terminal improvements during the last fifteen years.

There is a general acceptance of the principle of regulation of transportation by railroads, but it is Mr. Barnes' belief that in the past this regulation has been over-rigid and shortsighted. It destroyed the current earning power of the railroads and undermined their credit, leaving them unable to adequately expand their facilities with the increasing tonnage of the country and in anticipation of future growth. It is becoming clearer and clearer that enlightened self-interest requires a fair and even generous interpretation of regulation of these great arteries of commerce, but before large investments are made in terminal or special facilities and equipment of railroads, there should be a comprehensive survey of the future of transportation in all its various forms, and then intelligent preparation to utilize them in caring for the expanding commerce of the country.

The other aspect of the railroad problem in which the railroads figure as an industry that can spend money and provide business for others, is considered in an editorial in The New York *Times* of February 7, 1923. According to this, railway construction would rival building construction if the companies were helped or even let alone. Chicago is planning a union station which will exceed in size either of those in New York. The Illinois Central alone needs to spend forty-five million dollars. All railroads would spend the billion they should spend in the aggregate to give necessary facilities, if they were allowed reasonable profits with which to solidify their credit. It would be an enormous relief to the industrial situation if the railroads were permitted to finance themselves. The vitalizing of twenty billions of capital would strengthen the domestic financial situation quite as much as foreign purchases of our excess food production stimulate our farmers. Railroad consumption forms a larger proportion of the domestic iron and steel demand than the foreign demand does of the total of our agricultural products.

In this connection, however, it should be remembered, that although in 1907 the railroads were the largest consumers of steel and iron, today sheets, plates and pipe for general industrial use are the major products of the iron and steel industry, this of course being largely due to the fact that the railroads did not keep up with the country in their expansion.

There are many indications, however, that the outlook for the future is brightening. After all it was not lack of capital in the country that prevented the development of the railroads, but lack of good will in certain powerful groups and resulting lack of confidence in the future of the railroads among the general investing public. There has been of late a vigorous effort to reëstablish good will toward the railroads and a healthier spirit of coöperation is now being exhibited by the public generally, and by the governments of the various states in particular. Regardless of what our individual opinions concerning railroad management may be, the country needs successful and efficient railroads perhaps more than it needs anything else, and every effort within reason should be promptly directed toward making them both successful and efficient.

International Coöperation in Research

IN A RECENT communication William Henry Patchell, vice-president of the Institution of Mechanical Engineers of Great Britain, and a recent visitor to America, made a plea for the closer coöperation in research of the engineering societies of English-speaking countries. During his visit to America Mr. Patchell found that investigations on similar subjects were occupying the attentions of both British and American engineers, notably the work in steam, an investigation on steam flow through nozzles, and the codes for testing engines and boilers. Mr. Patchell suggested that an immediate solution might be the appointment of corresponding members by The American Society of Mechanical Engineers and the Institution of Mechanical Engineers on the Steam Nozzles Research and Steam Research Committees, respectively. Such contact would expedite the formulation of codes and provide opportunity for international criticism which would clarify the field and look toward the possible adoption of international codes and correlated international research.

It goes without saying that any relations set up between national engineering societies will be helpful in cementing permanent affiliations.

American engineers will gratefully receive this fortunate expression of coöperation from Mr. Patchell, an outstanding man in his profession in England, having been honored not only by being chosen as vice-president of the Institution of Mechanical Engineers, but also as vice-president of the Institution of Electrical Engineers. American mechanical engineers will recall his leadership in the use of large boilers at the Bow Street Station, London, in 1905 and his memorable paper dealing with superheater experiments in 1896.

The Federated American Engineering Societies

AN OUTSTANDING result of the recent annual meeting of the American Engineering Council was the quickening of the sense of responsibility in each member of the Council for the establishment of a more complete understanding of the aims and objects of The Federated American Engineering Societies in the minds of the individual members of the constituent organizations. That the Federation is dependent for its growth and success upon the unswerving loyalty and increased activity of each Council member was emphasized by President Cooley, doubly stressed by Executive-Secretary Wallace, and touched on again and again during the two days of the meeting.

The Council adopted a resolution "That it shall be the established policy of the F.A.E.S. to advise its member societies promptly and as fully as obligations of confidence will permit, of the consideration or the undertaking of all matters of material interest and to seek and obtain the advice and counsel of the member societies so far as that can be done without delay or detriment to the matter under consideration." This resolution was proposed by John Lyle Harrington as chairman of the A.S.M.E. delegation to the Council. The debate lasted over two hours. While its adoption puts a responsibility upon the American Engineering Council to advise and consult, there is a still greater responsibility upon the delegates to the Council and the governing bodies of the constituent societies to organize so that the desires and opinions of the individuals making up the member organizations may be available promptly for the guidance of the American Engineering Council and its Executive Board. Gladly shouldering this responsibility, the A.S.M.E. delegates to the American Engineering Council during the coming months will address individual members of the Society and Local Sections officers for expressions of opinion on various activities that the F.A.E.S. is carrying on, and will solicit suggestions for new activities for The Federated American Engineering Societies.

Engineers must grasp the remarkable opportunity offered by the F.A.E.S. to demonstrate the leadership of their profession in solving the tremendous economic and industrial problems facing this country.

L. P. Alford.[1]

The Engineer in Public Life

THE KEYNOTE of the annual meeting of the American Engineering Council was struck by Dean M. E. Cooley, in his presidential address, as follows: "We are, I feel, entering upon a new era. The engineer, not so much in the technical as in the social sense, is about to take that part in the world which rightfully is his. I am speaking not of civil engineering, mechanical engineering, chemical engineering, electrical engineering, or any other branch of engineering, but of the engineering profession as a whole........After fifteen months of service as president of the Federation I am convinced that the opportunities of the engineer are very great. I have the utmost faith that the engineering profession of this country and, through affiliation with foreign organizations, of the world, can bring to pass a new epoch in man's history."

This attitude has recently been expressed by the technical press, as shown in the following extracts.

Public Service and the Engineer

"Five engineers constitute the personnel of a rapid-transit commission brought into being at Detroit. Engineers as such will take satisfaction in the appointment. Formerly these engineers would have been employed as members of the staff, but here is public recognition that technical ability and executive ability may be found in the same man. There is a tendency for engineers to think of themselves as representing a quality of mind not possessed by others. It is true they are not so bound by tradition as are many other members of the community and they think in terms of the future as well as the present, in a day of industrial marvels. Also they are growing numerically strong, for the broadening range of engineering undertakings has held out promising opportunities, and the conspicuous successes the best brains have won in industrial life and in public places have brought high credit to the profession. Promotion activities like those of The Federated American Engineering Societies have done their part in bringing such recognition, and so has the equipment the average engineer now brings to his task."—*Iron Age*. February 1, 1923, p. 361.

The Engineer in Civic Life

"Recent developments (referring to the appointment of Prince Caetani as ambassador from Italy, to the adoption of American management methods by Czechoslovakia, and to the work of the F.A.E.S.) indicate the occurrence of two interesting events—the realization by the public of the service it can command from the engineer and the awakening of the engineer to the fact that he can be a valuable public servant.

"'Engineering thinking' and 'the engineering approach' may perhaps have fallen to the status of mere catchwords, but there is nevertheless a real need for the methods of the engineer in public office, and the more of him this country can induce to enter its service, the better."—*American Machinist*, January 25, 1923, p. 166.

The same issue of the *American Machinist* (p. 158) quotes from an address by Dr. J. A. L. Waddell, a consulting engineer of New York City, before the engineering students of the University of Barcelona, with the comment that although the engineer has begun to interest himself in politics and to make himself felt in this field, there is still much to be desired from those engaged in all classes of engineering work. Dr. Waddell's statement is as follows:

> Every individual should pay proper attention to his duties as a citizen of the country in which he resides. Engineers in America are great sinners in this particular; and the result is that our profession has very little to say regarding the government of our country. In the Administration, the Senate, and the House of Representatives at Washington engineers are generally conspicuous by their absence. This is a condition that should be corrected as soon as possible, for the benefit not only of our profession but also of that of the country, because who is there so competent in thought and action as an engineer?
>
> In European countries, I believe, engineers take a more prominent part in politics than they do in the U. S. A.—for instance, in Italy there are twenty-three engineers who are members of parliament. What the conditions in Spain are I do not know; but I notice that the Alcalde of Barcelona is a distinguished engineer.

In an editorial on The Federated American Engineering Societies in *Power* for January 30, 1923, Fred R. Low makes the following pertinent statement:

"The orderly reorganization of a system of diversified and often conflicting self-centered interests into an interlocking system of production, transportation and distribution devoid of wasted effort and lost motion; the impressment of the necessary regulative and directional forces without cramping initiative and motivating purpose; must be done against the inertia and resistance of established privilege and with the repression of unreasoning radicalism.

"The belief is growing that the unemotional, analytical, practical engineering type of mind and of man must be looked to to bring this about."

Indiana Engineering Society

The twenty-ninth organization to join the F.A.E.S. is the Indiana Engineering Society, comprising a membership of nearly 400. The object of this association, which has its headquarters in Indianapolis, is "the encouragement of professional intercourse between the engineer and surveyors of the State of Indiana, and the advancement of its members in scientific research in the various branches of engineering."

While public service is not included in this clause from the constitution of the Society, Indiana has ever had the coöperation of this group of engineers in such matters of public concern as flood prevention, sewerage, road construction, and water works. The president of the society is W. H. Elliott and its secretary is Charles Brossman.

[1] **Vice-Chairman, A.S.M.E. Representatives on American Engineering Council.**

Engineering and Industrial Standardization

Standardization of Methods of Testing Wood Now Under Way

INNUMERABLE misunderstandings and disagreements concerning strength of lumber and timbers, and such accidents as grow out of miscalculation of the strength of various kinds of lumber, should be greatly reduced as a result of the standardization of methods of testing wood, recently undertaken by the many interests involved, under the auspices of the American Engineering Standards Committee.

The U. S. Forest Service and the American Society for Testing Materials have been appointed joint sponsors for this undertaking, and 16 additional organizations are represented on the sectional committee which is to make an intensive study of the subject.

The scope of the committee's activities embraces the standardization of physical (including mechanical) tests of wood specimens. Of immediate importance is the application of these tests to (*a*) small clear specimens, and (*b*) structural timbers. The most important desideratum involved is the establishment of standard practice in testing wood which will make data obtained at different sources of the broadest possible value and insure the attainment of comparable results.

L. J. Markwardt of the Forest Products Laboratories at Madison, Wisconsin, has been elected chairman of the sectional committee and Prof. M. O. Withey, Professor of Mechanics, University of Wisconsin, secretary.

Automobile Headlight-Testing Specifications Approved by A.E.S.C.

ONE of the tribulations of the touring motorist—the hopeless attempt to comply with the automobile headlighting regulations of all states through which he passes on his trip across the continent—will be removed as soon as the various state motor-vehicle departments have all adopted the Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles which has just been approved by the American Engineering Standards Committee. Nine states have already indicated that they will adopt the specifications, while in three they are already in effect.

These specifications were submitted to the A.E.S.C. by the Illuminating Engineering Society. This organization and the Society of Automotive Engineers have been appointed joint sponsors for any revision and further development of the code which may be necessary. Approval of the specifications was recommended to the American Engineering Standards Committee by a Special Committee which had been appointed to investigate their practicability and acceptability. This Committee, of which David Van Schaack, vice-president of the National Safety Council, was chairman, was made up of representatives of the automobile manufacturing industry, automobile accessory manufacturers, the officials of motor-vehicle regulatory bodies, insurance companies, safety organizations, technical societies, and of the U. S. Bureau of Standards.

Safety Code for Power Presses and Foot and Hand Presses

THE use of power presses and foot and hand presses for stamping and forming pieces of metal and other material has grown so rapidly, and the loss of hands or fingers on these presses as commonly operated is so frequent, that this hazard has become one of the most serious mechanical problems in accident prevention.

This code is one of a number of safety codes which have been or are being formulated under the general auspices of the American Engineering Standards Committee. One purpose of the code is to serve as a guide to state authorities. Part I includes such requirements as may properly be enforced by a state industrial commission or labor department such as the location and installation of presses, feeding and removing material, making and setting of dies, and operating rules. Part II contains illustrated descriptions and discussions of press hazards and the methods that have been used to remove or protect against them. Both parts are fully illustrated.

This code, sponsored by the National Safety Council, was formulated by a committee of twenty-one men, including two representatives of the manufacturers of presses, five users of presses, one representative of employers, five governmental bodies, five specialists in the subject of power-press operation and safety, and three insurance representatives. Mr. C. B. Auel, manager, employees' service department, Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa., was Chairman of the Sectional Committee, and Mr. S. J. Williams, chief engineer, National Safety Council, 168 N. Michigan Ave., Chicago, Ill., was its secretary. For copies of this code address the National Safety Council.

Building Code Committee Issues First of Its Series of Reports

INVESTIGATIONS by a Congressional Committee during 1919 and 1920 disclosed the fact that existing building laws through variations and inconsistencies of their provisions and through unduly restrictive or expensive requirements, were operating to prevent needed activity in the building industry. That these conditions might be remedied, a committee of experienced engineers and architects was organized by Secretary Hoover, to investigate building practice and code requirements and to prepare standard building regulations based on the latest and best information, which might be recommended to cities and states adopting or revising building codes.

In order that its recommendations might have sound bases of information and opinion, the committee is coöperating with nearly one hundred engineering and architectural societies, builders' exchanges, and industrial organizations producing building materials. Special questions also are referred to large groups of individual engineers, architects, building officials, to the Bureau of Standards, and to others whose experience qualifies them to discuss such subjects.

Owing to the pressing need for dwelling houses the first report of this Committee only presents recommendations for the construction of one and two-family houses having exterior walls of solid or hollow masonry, concrete, and frame, the latter including veneer and stucco surfaces.

The Committee recommends that building codes permit 8-in. solid brick and 6-in. solid concrete walls for $2^1/_2$ and 3-story dwellings accommodating not more than two families each; that 8-in. hollow building tile, hollow concrete block, or hollow walls of brick (all rolok) shall not exceed 20 ft. in height to the gables; and that frame construction be limited to $2^1/_2$ stories. Metal lath and plaster on wood studs properly firestopped is approved for party and division walls, but at least every alternate wall in row houses must be 8-in. solid brick or concrete or 12-in. hollow building tile, concrete block, or hollow wall of brick.

The report recommends revised working stresses for timber used in dwellings, based on investigations of the U. S. Forest Products Laboratory. Live loads to be required as bases for design are 40 lb. per sq. ft. for floors of wood, and 30 for those of monolithic type, or of solid or ribbed slabs. Foundation walls of brick are required to be 12 in. thick for excavated enclosures, and similar concrete walls shall be as thick as the walls they support but not less than 8 in. Special hollow building tile 12 in. thick is permitted for foundation walls of frame buildings. Detailed recommendations are given for firestopping and chimney construction, also for treatment of built-in garages.

Subsequent reports will deal with the construction of multifamily dwellings, hotels, clubs, office buildings, stores and other mercantile buildings, factories, work shops, amusement places, churches, institutions, schools, public buildings, garages, and other non-residential buildings.

The Committee is composed of the following members: Ira

H. Woolson, Chairman, consulting engineer, National Board of Fire Underwriters, New York City; Edwin H. Brown, architect, Minneapolis, Minn.; William K. Hatt, professor of civil engineering, Purdue University, Lafayette, Ind.; Rudolph P. Miller, formerly supt. of buildings, New York City; John A. Newlin, in charge of section of timber mechanics, Forest Products Laboratory, Madison, Wisconsin; Ernest J. Russell, architect, St. Louis, Mo.; and Joseph R. Worchester consulting engineer, Boston, Mass.

This report, comprising 100 pages and thirty illustrations, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 15 cents.

Bureau of Standards Conducts Investigation on Welded Pressure Vessels

MEAGERNESS of scientific data on which to base proper requirements for safety without placing unjust restrictions on the use of welding has raised a difficult problem for the Boiler Code Committee of The American Society of Mechanical Engineers in its effort to draw up a code to govern the construction of unfired pressure vessels. However, with the coöperation of the American Bureau of Welding, which is the advisory committee on welding research for the American Welding Society and the National Research Council, a Pressure Vessel Committee was appointed to coöperate with the Boiler Code Committee and a series of tests was arranged to be carried out by the United States Bureau of Standards. Eight manufacturers placed forty tanks at the disposal of the Committee and provided funds for the test. A hydrostatic and hammer test was finally decided upon to determine whether a vessel was safe for the purpose for which it was designed.

The shells of most of the tanks were 6 ft. long and 2 ft. in diameter, and made of $^3/_8$-in. mild steel plate. Both electric and oxy-acetylene welding were used. The hydrostatic and hammer test developed that the welded pressure vessel, according to the regular formulas for working pressure, has a factor of safety of about 6.

A remarkable feature of this undertaking is the rapidity of accomplishment. The first meeting of the committee was held in New York on August 17 last, and a plan outlined. The tanks called for in the program were immediately built by manufacturers distributed widely (one of them on the Pacific Coast), and shipped to the Bureau of Standards in Washington. Most of the tanks arrived by the first of December. Under the supervision of Dr. H. L. Whittemore, Chief of Section VII-1, Physical Tests of Structural Materials Division, who is also chairman of the Committee, testing was started December 4 and carried on continuously to January 10. Many visitors, including members of the Boiler Code Committee, insurance inspectors, tank manufacturers, American Welding Society and National Research Council, have witnessed the tests.

A complete report will appear in the April issue of Mechanical Engineering.

Boiler-Furnace Refractories

THE subject of Refractories and their relation to the furnace problem of modern central stations drew an interested audience to the meeting of the Metropolitan Section of the A.S.M.E. in New York City on January 23. Kenneth Seaver[1] in a very interesting talk, told of the problems of the manufacturer of firebrick and pointed out the manufacturing difficulties that must be overcome by proper furnace design and construction. Mr. Seaver emphasized that the main dependence of the power-plant operator is ordinary firebrick, for silica brick, which is suitable for high temperatures, such as are achieved in metallurgical work, is unstable for boiler settings on account of its contraction and expansion in the lower temperature ranges. Long freight hauls for firebrick are uneconomical and therefore brick made from clay handy to the user must be employed. This makes standardization of material very difficult, but the manufacturer, by study of the clays available in each district, may obtain the best results by compounding or other treatment. The operating engineer requires uniform sizes of firebrick, as thin joints, which seem essential to long furnace life, are impossible where firebrick vary in thickness. Mr. Seaver pointed out that variations in sizes are due only partly to the effect of heat in the kiln and mostly to the effect of variation in pressure in the different layers. He told of methods being employed, by certain power plants in the construction and repair of furnaces, such as spraying the inside of the furnace with a half-inch layer of high-temperature cement, or the use of relieving arches, or, by slight changes in form or location, correcting improper draft distribution. In the discussion the importance of uniformity was again emphasized by firebrick users. Edwin B. Ricketts[1] stated that the troubles due to high furnace temperatures might be solved by locating passages in the walls through which air may be passed on its way to the combustion chamber.

[1] Chief Engineer, Harbison-Walker Refractories Co. Pittsburgh, Pa. Mem. Am.Soc.M.E.

[1] Asst. Chief Operating Engineer, New York Edison Co. Mem. Am.Soc. M.E.

MEETINGS OF OTHER SOCIETIES

American Institute of Chemical Engineers

Historic and industrial Richmond was headquarters for the fifteenth annual meeting of the American Institute of Chemical Engineers, held December 6 to 9, 1922, inclusive. The excursion program included trips to points made famous by the Civil War as well as to modern industrial plants. A large delegation visited the Virginia-Carolina Chemical Company's plant, where sulphuric acid, acid phosphate, and mixed fertilizers are made. Materials handling has been reduced to a minimum in this plant; transportation is carried out on elevated tracks by means of an electric engine and also by means of electric cranes on either side of the building. At Hopewell, which now has a population of some 9000 and contains a number of thriving industrial plants, the Hummel-Ross pulp factory was inspected. The Richmond Cedar Works, the Richmond Car Works, the Standard Blotting Paper Co., and other industrial plants were also visited. An inspection of the tobacco factories was preceded by an instructive address by T. M. Carrington, president of the Tobacco Association of the United States, on the American tobacco industry. Of special interest were the automatic packing and wrapping machines used in the factories.

The technical program of the meeting contained a number of papers of general interest. A. E. Marshall, of Baltimore, Md., spoke on the use of pyrex glass as an engineering material. Dr. J. R. Young, Mellon Institute, outlined the development of asbestos-protected metal. Three papers on the absorption of gases in towers were presented: F. C. Blake, of the Du Pont Company, discussed the resistance of packing to fluid flow and W. B. Van Arsdale, of the Brown Company, and Prof. R. T. Haslam, Massachusetts Institute of Technology, the effect of rate of flow on absorption. Among other topics considered were the various uses of wood and concrete in chemical industries, waterproofing concrete, and stirrer performance.

American Petroleum Institute

The third annual meeting of the American Petroleum Institute was held in St. Louis, Mo., December 6, 7, and 8, 1922. It was preceded by a meeting of the Association of Natural Gasoline Manufacturers, making a four-day convention for the consideration of problems of the oil industry, a number of which involve mechanical engineering. Among the subjects discussed at general and group sessions were standardization of equipment, internal-combustion engines, natural gasoline as a motor fuel, and the relation of the "knock" to the gasoline problem.

Under the general topic of standardization, simplification and improvement of oil-drilling methods and equipment a number of important papers were presented. S. F. Speller, National Tube Co., discussed the physical qualities of pipe, with special reference to iron, bessemer steel, and open-hearth steel, and the activities of the Mid-Continent Oil Gas Association regrading pipe for deep-well drilling were recounted by J. Edgar Pew, of The Sun Co. Drilling

equipment, from the point of view of the essential qualities and analysis of raw materials entering into its manufacture, and also the value of heat treatment, was the subject of an address by Prof. F. F. McIntosh, of the Carnegie Institute of Technology. Papers on the standardization of tool joints, rig irons, and cable tools were followed by a general discussion of the question, What Does the Oil Industry Wish to Do About Standardization? This subject of standardization in the oil industry was also discussed at one of the sessions from the points of view of the engineer, the field man, and the supply manufacturer.

Several group sessions were devoted to the subject, What is Good Gasoline? Dr. S. W. Stratton, of the Bureau of Standards, gave the answer as so far formed by the joint research program of the Bureau and the oil and automotive industries. Thomas Midgley, Jr., General Motors Research Corporation, pointed out the relationship of "knock" to the gasoline problem and discussed the remedy for knocking. A paper on the use of natural gasoline in motor fuel was presented by O. P. Kenney, of the Tide Water Oil Co., at a session of the Association of Natural Gasoline Manufacturers. Henry L. Doherty, New York, gave his interpretation of the problem of heavy fuels for internal-combustion engines.

Society of Automotive Engineers

An unusual educational opportunity was afforded automotive engineers and executives during the week of January 8, when two automobile shows and the annual meeting of the Society of Automotive Engineers were held in New York City. S.A.E. members attending the annual meeting were guests at both the National Automobile Show and the Automobile Body Builders' Show, and it is more than probable that their inspection and study of new developments displayed at the shows gave impetus to their discussion at the sessions of the annual meeting.

There were seven technical sessions, two on body engineering, and one each on engine cooling, aeronautics, fuels, detonation, and research. One of the most novel ideas brought out during the meeting was a new all-fabric closed body described in a paper on Cheaper Closed Body Construction, presented at a body engineering session, by George J. Mercer, of Detroit, Mich. This body consists of a wire-covered wood frame on which are applied a layer of heavy buckram and a covering of highly finished fabric. Mr. Mercer outlined the merits of the fabric body and stated that he expected to put it on the road in the near future in order to determine its durability.

At the same session J. B. Davis, of the Standard Textile Products Co., New York, N. Y., described methods of testing leather substitutes and top material recently developed by his concern in coöperation with the Bureau of Standards and the Society for Testing Materials.

Testing automobile finishing varnish was the subject of a paper by L. Valentine Pulsifer, chief chemist, Valentine & Co., New York, N. Y. Mr. Pulsifer stated that the three most important factors in estimating the service-giving qualities of varnish are elasticity, moisture resistance, and film thickness. Mr. Pulsifer performed actual tests for these qualities and discussed the testing of varnish qualities in general.

The fourth paper presented at the body engineering sessions was by F. F. Murray, advisory mechanical engineer, Hardwood Manufacturers' Institute, Chicago, and dealt with the needless waste of hardwood lumber in the automotive industry. He pointed out that the cost of body production could be considerably reduced by a revision of specifications for grading, and commended the work of the Central Committee on Lumber Standards which is endeavoring to produce a new and scientific grading schedule that by common accord will establish a lasting instrument to be entitled the American Lumber Standards.

A symposium of papers on commercial airplane design was held on the evening of January 9. Prof. E. P. Warner, Massachusetts Institute of Technology, named economy, safety, speed, and comfort as qualities which the finished plane should possess, and discussed the relative importance of these factors. Other speakers spoke of the obligation which the Government has in carrying forward development, and possibilities of commercial aviation, emphasizing the necessity for "selling" the public as to its safety and practicability.

At the detonation session Thomas Midgley, Jr., of the Dayton Research Laboratories, outlined the prevailing theories of detonation and described experiments which he has conducted to determine the laws governing detonation. S. M. Lee and S. W. Sparrow, of the Bureau of Standards, described methods used and results obtained in two investigations of fuels for high-compression aviation engines. A paper by J. H. Hollaway, H. A. Huebotter, and G. A. Young, all of whom are connected with Purdue University, discussed their research work into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation.

Reports on fuel-volatility research at the Bureau of Standards, and on the work of the research department of the S.A.E., especially in regard to fuels, were presented at a research session of the meeting. At the fuel session, papers on the effective volatility of motor fuels, the proper utilization of natural gasoline, and a survey of gasoline and kerosene carburation were presented. The latter paper gave a general discussion of gasoline carburation requirements, the use of petroleum fuels, and reasons for the present wastage of fuel by improper carburation.

An interesting paper on aircraft-engine practice as applied to air-cooled passenger-car engines was presented at the engine-cooling session. This article showed wherein the automobile designer and engine builder can profit by the use of practice developed for air-cooled aircraft engines and contained a detailed discussion regarding cylinder design and performance, inclusive of valve location, type of finning, and form of cylinder head.

Elisha Lee, vice-president of the Pennsylvania Railroad, was the chief speaker at the annual dinner of the society. His subject was motor transport and our railroads, a problem in coördination. Herbert W. Alden, chief engineer, Timken-Detroit Axle Co., newly-elected president of the society, reviewed its progress during 1922 and announced that emphasis during 1923 would be laid upon production engineering.

American Society of Civil Engineers

The conferring of five honorary memberships, the election of Charles F. Loweth as president, meetings of four new technical divisions, reports of technical committees, an all-day excursion to Bethlehem, and technical sessions on engineering education, engineering research, and city planning—all these were outstanding events in the seventieth annual meeting of the American Society of Civil Engineers, held in New York January 17, 18, and 19, 1923.

The recipients of honorary memberships were Leon-Jean Chagnaud, Paris, noted for his subaqueous and subterranean excavation work; Sir Maurice Fitzmaurice, London, internationally prominent through his achievements in bridge engineering and irrigation and drainage work; Clemens Herschel, New York, past-president of the A.S.C.E., the inventor of the venturi meter; John Frank Stevens, New York, railroad engineer and well known for his work as chief engineer of the Panama Canal; and William Cawthorne Unwin, London, engineering educator and authority, honorary member A.S.M.E. and recipient of the Kelvin Medal in 1921.

Charles F. Loweth, who succeeds John R. Freeman as president, has been chief engineer of the Chicago, Milwaukee & St. Paul Railway since December, 1910. He has been active in the work of the society, serving as director and vice-president, and rendered valuable service as its representative on Engineering Council.

With the formation of four technical divisions, the A.S.C.E. has joined the ranks of those large engineering organizations which are recognizing the potentialities of such specialized branches. The technical division on sanitary engineering, which had previously been organized, held its first general meeting on January 16. H. P. Eddy, consulting engineer, Boston, Mass., read a paper on the Present Status of Sanitary Engineering and made valuable suggestions as to the aims of the division. Organization meetings of the three other divisions, on irrigation engineering, highway engineering, and power, were held on January 19. Tentative organizations and plans for procedure were drawn up and lines of work to be carried on by the divisions were discussed.

An all-day excursion to Bethlehem on January 18 included inspection of the new Hill-to-Hill bridge, which is 62 ft. wide and, with its approaches, about 6000 ft. long; the works of the Bethlehem Steel Company, especially the open-hearth department, the rolling

mill, and the fabricating shops; and the John Fritz Laboratory at Lehigh University.

Among the committee reports which were presented was the third report on stresses in railroad track, covering a study of curved track; the final report on bridge specifications, which differs from other current specifications in that it is shorter and restricts itself to general considerations, leaving details to the individual engineer; and a summary of tests of impact in highway bridges.

At the session on engineering education Charles F. Scott, professor of electrical engineering, Sheffield Scientific School, reviewed what is being done by various societies for the promotion of engineering education, and outlined the new project of the Society for the Promotion of Engineering Education; this was described in an editorial by him in the February issue of Mechanical Engineering. The Outlook of the Engineering Colleges of the Middle West was the subject of an address by William G. Raymond, dean of the College of Applied Science, State University of Iowa. A paper by Magnus W. Alexander, managing director of the National Industrial Conference Board, read by Mr. Trowbridge, a member of his staff, emphasized that the engineer, animated by his constant spirit of inquiry, should guide industry in basing its work upon ascertained fact and experience. John L. Harrington, president of the A.S.M.E., urged the coöperation of the national societies in a plan for a general undergraduate engineering society, directed by the students themselves rather than by the national societies or faculties.

The speakers at the research session were Arthur N. Talbot professor of municipal and sanitary engineering, University of Illinois; Alfred D. Flinn, director of Engineering Foundation and chairman of the Division of Engineering, National Research Council; George K. Burgess, chief of the Division of Metallurgy, U. S. Bureau of Standards; and Otto B. Blackwell, transmission development engineer, American Telephone and Telegraph Company, New York.

Mr. Talbot, who is a past-president of the civil engineers and chairman of their committee on research, discussed the society's research program, which has included such important subjects as working stresses for steel structures, flood-protection data, irrigation engineering, hydraulic phenomena, and impact in highway bridges. Mr. Flinn reviewed the development of the two organizations in which he is active, as previously named, stating that each of them is "an integral part of the organism of the founder societies, just as the Library is." Mr. Burgess reviewed the present status and probable future of steel as a structural material and outlined some of the work being carried on at the Bureau of Standards.

Subjects considered at the city planning session were parks and parkways, city planning and the engineer, zoning, and regional planning.

At an evening session on January 18 Julius H. Barnes, president of the U. S. Chamber of Commerce, presented an address on Transportation Keyed to Production, in which he emphasized the necessity for adequate transportation facilities for distribution of products.

LIBRARY NOTES AND BOOK REVIEWS

American Machinist Gear Book. By Charles H. Logue; revised by Reginald Trautschold. Third edition. McGraw-Hill Book Co., New York, 1922 Cloth, 6 × 9 in., 353 pp., illus., diagrams, tables, $3.

This book is intended to give practical data for cutting, molding, rolling and designing commercial types of gears, and to present this information by means of simple rules, diagrams and tables arranged for ready reference. This edition has been carefully revised and enlarged. Matter of little practical value has been omitted. The chief additions relate to spiral type and Williams "master form" bench gears, to the Williams system of internal gearing and rolled gearing. The last subject is here first presented in book form.

Annuaire du Bureau des Longitudes. 1923 By France: Bureau des Longitudes. Gauthier-Villars et Cie, Paris, 1922. Paper, 4 × 6 in., 860 pp., portrait, maps, tables, 6 fr. 5 c.

This convenient reference book has appeared annually for 128 years. The volume for 1923, like its predecessors, covers a wide field of statistical information, astronomical, physical, geographical and social. Five star maps are included, and an extensive review of the climate of France.

Cours Complet de Mathématiques Spéciales; Vol. 3, Méchanique. By J. Haag. Gauthier-Villars et Cie, Paris, 1922. Paper, 6 × 10 in., 188 pp. 12 fr.

In this volume on mechanics, Professor Haag lays emphasis on the experimental origin of that science, even though he proves that an entirely abstract exposition of it may be given, as of any other mathematical theory. His study begins with kinematics, from which topic he proceeds to dynamics and finally to statics, which is considered as a particular case of dynamics. Although primarily a work on theoretical mechanics, applied mechanics has not been neglected, but has been included by a large number of problems that occur in physics or in industry.

Dictionary of Applied Chemistry. Vol. 4. By Sir Edward Thorpe. Longmans, Green & Co., New York, 1922. Cloth, 6 × 9 in., 740 pp., $20.

This well-known work of reference has been thoroughly revised and brought down to date, the present volume including matter published as recently as 1922. Volume 4 includes many subjects of technical interest, such as the manufacture of matches, of nitric acid; the utilization of atmospheric nitrogen; the metallurgy of lead, magnesium, nickel, mercury, osmium and molybdenum metallography; mercerizing; leather; naphthalene. Extensive articles on these and other topics, by well-known authorities, characterize the book.

The Dynamo, Its Theory, Design and Manufacture. Vol. 1. By C. C. Hawkins. Sixth edition. Isaac Pitman & Sons, New York, 1922. Cloth, 6 × 9 in., 615 pp., illus., diagrams. $6.

A standard British text of comprehensive character, covering both direct- and alternating-current generators. In this revision greater space is given to the treatment of the electromotive force of the dynamo by vectorial methods, the theory of armature winding has been reconsidered and expanded, and greater prominence is given to drum armatures. A section on the oscillation of a mechanical system, a discussion of the compressive stress on the mica plates in high-speed commutators, and the winding of shunt coils with two sizes of wire are among the new matters that have been added. The book has been largely rewritten and carefully revised.

Elementary Internal-Combustion Engines. By J. W. Kershaw. Second edition. Longmans, Green & Co., New York, 1922. Cloth, 5 × 7 in, 211 pp., diagrams. $1.75.

An elementary account of the construction and working of oil and gas engines and power-gas producers, intended as an introduction to more advanced books.

Internal-Combustion Engines. By J. Okill. Isaac Pitman & Sons, New York, 1922 (Pitman's Common commodities and industries). Cloth, 5 × 7 in., 126 pp, illus. $1.

A review of the development and construction of the various types of internal-combustion engines, written to show how gas and oil engines stand as competitors to steam for all power purposes, and to discuss some of the power requirements that are beyond the scope of the steam engine.

Introduction to Theoretical and Applied Colloid Chemistry By Wolfgang Ostwald. Second American edition, translated from the eighth German edition by M. H. Fischer. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 266 pp., illus., diagrams, portrait. $2.50.

A revised and enlarged edition of the principal lectures delivered by the author during his American visit in 1913–1914. These lectures were intended for those with little or no knowledge of colloid chemistry and were intended as a general survey of the

subject, with particular emphasis upon its great possibilities of scientific and technical application.

Experimental Electrical Engineering and Manual for Electrical Testing. Vol. 1. By Vladimir Karapetoff. Third edition. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 795 pp., illus., diagrams. $6.

This textbook on the testing of electrical machinery is based on the course of instruction given by the author at Cornell University, but the selection of material has been modified by comparison with the courses in other colleges, so that the book presents a composite picture of what is actually taught in the electrical laboratories in this country. This edition has been completely revised and reset. Volume 1 contains all elementary experiments and is sufficient for the needs of general students. Volume 2 contains advanced work needed by students of electrical engineering.

Jigs and Fixtures. By Fred H. Colvin and Lucian L. Haas. Second edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in. 237 pp., illus., diagrams, tables. $2.50.

The authors endeavor to present the fundamental principles of design, arranged as nearly in the order of their application as possible, so that the tool designer can select such parts and methods as seem best suited to any problem. The new edition has been enlarged to include a greater variety of work and also to show a few boring bars and reamers.

Labor Turnover in Industry. By Paul Frederick Brissenden and Emil Frankel. Macmillan Co., New York, 1922. Cloth, 6 × 9 in., 215 pp., tables. $3.50.

The questions discussed in this work include the general extent of labor mobility; labor mobility in individual plants and in special groups within the work force, causes of turnover, seasonal influences, effects of length of service, responsibility for instability. The investigation is based on statistics collected for the United States Bureau of Labor Statistics, from over 260 establishments employing over 500,000 workers. The problem is treated primarily from the point of view of the individual establishment.

Machinery Foundations and Erection. By Terrell Croft. First edition McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 8 in., 691 pp., illus., diagrams. $5.

Section 1 of this book considers the general requirements that foundations for machinery must meet. This statement of fundamentals is immediately followed by divisions treating of the design and properties of the different components of foundations, such as anchor bolts, anchor plates and anchors. Following these come instructions on the installation and reconstruction of foundations. The divisions in the next group give specific information on the design and construction of foundations for certain types of machinery, including steam engines and turbines, boilers, waterwheels, electrical machinery, hammers and planers. The concluding divisions explain methods for erecting machinery. The book is written for practical men, and avoids the use of higher mathematics. Little has been written previously on the subject.

Mechanical Engineering Detail Tables. By John P. Ross. Isaac Pitman & Sons, New York, 1923. Cloth, 5 × 7 in., 197 pp., diagrams, tables. $2.25.

This compilation, by an experienced draftsman, is intended to supply machine designers with the proportions of a number of machine details that are common to all machines. The tables include dimensions for the usual sizes of studs, rivets, nuts, bolts, handles, ratchets, wrenches, links, joints, shafting, keys, keyways, bearings, hooks, chains, engine and pump details, condenser details, valves and cocks, pipes, flanges and fittings, ship's fittings and wire ropes. Follows English practice.

Oil Power. By Sydney H. North. Isaac Pitman & Sons, New York, 1922 (Pitman's Common Commodities and Industries). Cloth, 5 × 7 in., 122 pp., illus., tables. $1.

A concise, yet comprehensive account of the use of oil for power production, which covers the subject in a general manner, without attempting great detail on its many aspects. Intended for engineers, shipowners and users of fuel. Gives special attention to the economic advantages of oil.

Practical Mechanics and Strength of Materials. By Charles W. Leigh. First edition. McGraw-Hill Book Co., New York, 1923. Cloth, 5 × 8 in., 293 pp., diagrams, tables. $2.25.

An elementary textbook presenting those principles of mechanics and strength of materials that are needed by the practical man. Intended for high schools and vocational schools.

Quantum Theory. By Fritz Reiche. E. P. Dutton & Co., New York, Cloth, 5 × 8 in., 183 pp. $2.50.

In this treatise the author has attempted to give in broad outline the most important features of the doctrine of quanta, its origin, its development and its ramifications. An appendix entitled Mathematical Notes and References provides a useful list of the important writings on the subject.

Die Statik des Eisenbaues. By W. L. Andrée. Second edition. R. Oldenbourg, Munich, Berlin, 1922. Paper, 6 × 10 in., 521 pp., diagrams, tables $3.

A practical handbook for the designer of steel structures, intended to give him a collection of the most useful methods for solving the problems of statics that arise in the design of ordinary structures. The book contains over one hundred examples, taken from practice, of steel buildings, shops, markets, craneways, hangars, shipways, conveyor frames, cooling towers, bridges, cableways, loading bridges, pontoon bridges, etc. In every case, the author has tried to present the most suitable method of calculation. An appendix presents, in concise form, the foundation and development of the most important method for statically indeterminate systems.

Treatise on the Principles and Practice of Dock Engineering. By Brysson Cunningham. Third edition. Charles Griffin & Co., London, 1922. Cloth, 6 × 9 in., 600 pp., illus., plates. $10.00.

Mr. Cunningham's treatise covers the subjects of dock design and construction; jetties, wharfs and piers; dock gates and caissons; sheds and warehouses; dock bridges and dock equipment. The book aims to be thorough, rather than extensive, in its treatment; and to investigate in detail rather than in general. This edition has been thoroughly revised and brought up to date by the inclusion of new material and illustrations.

Index to Volume 44 of Mechanical Engineering

THE Index to Volume 44 of Mechanical Engineering has recently been completed and is now available in printed form. Any member of The American Society of Mechanical Engineers or any other subscriber to the magazine may obtain a copy of this Index by sending a written request for it to the headquarters of the Society at 29 West 39th Street, New York, N. Y.

Acting Director of U. S. Standards Bureau

THE VACANCY caused by the resignation of Dr. S. W. Stratton as director of the U. S. Bureau of Standards has been filled temporarily by the appointment of Dr. Fay C. Brown as acting director. Dr. Brown has been assistant director since the War. He is a graduate of the University of Indiana and did graduate work at the Universities of Illinois and Chicago and at Princeton. He was instructor at the Universities of Illinois and Iowa previous to the War. In 1917 he entered the military service and was in charge of testing and ballistic work on airplane bombs.

New President of British Mining Engineers

THE INSTITUTION of Mining and Metallurgy, of England, which is international and comprises a large American membership, has selected Robert Gilman Brown as its president for 1923–1924. Mr. Brown is a graduate of Dartmouth and the Columbia School of Mines and was connected with various mining concerns in this country until 1907, when he went to England. He has since been associated, either as consulting engineer or director, with mining companies operating in Cornwall, North Wales, South America, Burma, and particularly in Russia. He has been a member of the council of the Institution for eleven years, and is the second American engineer to be its president, the first having been Hennen Jennings.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 111-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

Manless. The Army's Manless Airplane. Aerial Age, vol. 16, no. 2, Feb. 1923, p. 73. Results of experiments by Army Air Service to produce small airplane of 20-ft. span, with 60-hp. air-cooled engine, capable of carrying useful load of 250 lb., which would operate without pilot; equipped with Sperry automatic pilot.

AUTOMOBILE ENGINES

Motor-Truck. Type K-4 Continental Truck Engine Goes Into Production. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 231–232, 2 figs. Has detachable cylinder head and full-pressure lubrication; gives 35 hp. at 1300 r.p.m., at which speed it is intended to be governed; weight, 680 lb.

AUTOMOBILES

Bodies in Sections. Manufacturing and Shipping Costs Cut by Building Bodies in Sections, J. Edward Schipper. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 215–217, 7 figs. 30 broughams packed in same freight-car space as 14 under usual method; Oldsmobile plan provides for shipping in seven sections; bolted and screwed together in car factory.

BELTING

Leather. New Federal Specifications for Leather Belting, Louis W. Arny. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, p. 92. Discusses new specifications adopted by U. S. Government.

BOILER FURNACES

CO_2 Distribution. Stratification of Gases Within a Boiler Furnace, W. C. Strunk. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 166–168, 6 figs. Method of taking combustion-chamber gas samples; four sets of analyses show air distribution in furnaces; operation relation of CO_2 and O_2 shown; method suggested to improve combustion efficiency.

CARBURETORS

Venturi Diameters. Determining Correct Carburetor Size, W. H. Weber. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 220–221. Practical method for calculating cross-section of venturi tube necessary for carburetor to permit quick acceleration from minimum car speed in high gear.

DIE CASTING

Dies for. Dies for Die-Castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 6, Feb. 1923, pp. 430–432, 4 figs. Specific examples of design and construction of dies for making die castings of more intricate types.

Process and Equipment. Die Casting Process and Equipment, John W. Harriman. Am. Mach., vol. 58, no. 4, Jan. 25, 1923, pp. 137–141, 10 figs. Construction and operation of die; what to allow for shrinkage; methods of forcing molten metal into die are described.

DISKS

Rotating, Stresses in. Rotating Discs of Conical Profile. Engineering, vol. 115, nos. 2975 and 2978, Jan. 5 and 26, 1923, pp. 1–3 and 115–116, 4 figs. Determination of stresses due to centrifugal forces acting alone, application of load of, say, 1 lb. per in. run applied along knife edge forming periphery, and infinitely great pressure applied to the interior of an infinitely small hole drilled through the disk at its center.

GAS ENGINES

Steel Works. Large Gas Engines Installed in Steel Plants, C. G. Sprado. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 123–125, 5 figs. Comparison of B.t.u. recoveries by gas engines versus steam units; marked advance in valve-gear construction results in unexpected economy and capacity in new 3500-kw. machines.

GEAR CUTTING

Helical Gears. Methods of Generating Helical Gears, Franklin D. Jones. Machy. (N. Y.), vol. 29, no. 6, Feb. 1923, pp. 445–450, 15 figs. Methods of cutting teeth of helical gears on hobbing machines and gear shapers.

Sykes Generators. Large Sykes Gear Generators. Engineering, vol. 115, no. 2977, Jan. 19, 1923, p. 69, 11 figs. on p. 78 and supp. plate. Details of machines of two models, both capable of cutting wheels up to 15 ft. in diameter.

Tangent Rack Gears. Hobbing Tangent Rack Gears. Engineering, vol. 115, no. 2978, Jan. 26, 1923, pp. 106–107, 10 figs. Describes system of generating gearing by means of conical hob devised by H. E. Taylor of Hotchkiss et Cie., Coventry, England.

GEARS

Spiral Bevel. The Manufacture of Spiral Bevel Gears. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 32–36,13 figs., partly on p. 46. Describes works and methods used by E. N. V. Motors, Ltd., London.

INDICATORS

Steam-Engine. High-Speed Engine Indicators. Engineering, vol. 115, no. 2978, Jan. 26, 1923, pp. 119–126, 34 figs. Four papers read before Instn. Mech. Engrs. as follows: The Problems of the Engine Indicator, Loughnan Pendred; A New Form of Optical Indicator, F. W. Burstall; Micro-Indicator for High-Speed Engines, W. G. Collins; R. A. E. Electrical Indicator for High-Speed Internal-Combustion Engines, and Gauge for Maximum Pressures, Harry Wood.

Indicators for High-Speed Engines. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 31–32. Discusses optical indicators, including Hopkinson, Watson and Burstall in England, and Midgley, in America.

INDUSTRIAL MANAGEMENT

Engineering Department. The Successful Operation of an Engineering Department, W. E. Irish. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, pp. 93–97. Consideration of labor problems from engineer's viewpoint—men as "cogs," foremen as "bearings," etc. Shows how method has worked out in practice.

Lot-Quantity Determination. How to Determine Quantities for Lot Manufacture, Kenneth W. Stillman. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, pp. 84–86, 2 figs. Finding most economical lot quantity by graphs.

Production Methods. Undetected Faults in Production Processes, A. Whitehead. Engineer, vol. 135, no. 3499, Jan. 19, 1923, pp. 72–73, 1 fig. Points out influence of defects in workmanship or processes which ordinary methods of inspection commonly neglect.

IRON CASTINGS

Electric-Furnace. Gray Iron Castings from Electric Furnace, Larry J. Barton. Iron Age, vol. 111, no. 4, Jan. 25, 1923, pp. 269–273, 8 figs. Possibility of their commercial production; acid and basic practice compared; role of heat treatment.

JIGS

Design. Jigs and Tools, J. Moore. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 55–59, 13 figs. Considerations and principles of design. (Abstract.) Paper read before Instn. Production Engrs.

LOCOMOTIVE BOILERS

Washing-Out and Refilling Plant. Locomotive Washing-Out Plant for the Italian State Railways. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 42–44, 8 figs. Details of washing-out and refilling plant, underlying idea of which is to recover heat stored in boilers of locomotives returning to sheds, and use it in boilers of locomotives starting for day's work.

LOCOMOTIVES

Repairing. How Locomotives Are Repaired on Ford's Railway, Fred H. Colvin. Am. Mach., vol. 58, no. 4, Jan. 25, 1923, pp. 133–136, 14 figs. Describes repair shop at River Rouge and methods employed.

MONEL METAL

Forging. Considerations in the Forging of Monel Metal. Forging & Heat Treating, vol. 8, no. 12, Dec. 1922, pp. 542–545, 3 figs. Importance of heating in a reducing atmosphere or muffle furnace emphasized; correct temperature for forging; physical and chemical properties of monel metal.

MOTOR TRUCKS

Performance Tests. Production Tests of Loaded Chassis at the G. M. C. Truck Plant. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 224–226, 7 figs. To obtain more comprehensive and accurate data on truck chassis performance than would be possible through road tests, Gen. Motors Truck Co. has provided test room through which all completed chassis must pass.

OIL ENGINES

European. European Oil Engines, Edwin Lundgren. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 171–172, 3 figs. Discussion of correct air-oil mixing; the Deutz engine; new Hesselmann solid-injection engine.

OPEN-HEARTH FURNACES

Developments. Developments in the Open Hearth, Herbert F. Miller, Jr. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 48–51, 3 figs. Gas-producer development and possibilities of coke-oven gas; furnace valves, door frames and ports; suggestion of evolution of open-hearth similar to modern blast furnace.

PRESSES

Forging, Hydraulic. The Practical Side of the Design of Hydraulic Forging Presses, W. R. Ward. Forging & Heat Treating, vol. 8, no. 12, Dec. 1922, pp. 553–557, 5 figs. Detailed discussion of design; calculations and materials; application and limitations of various presses.

REFRIGERATING PLANTS

Performance Scale. A Performance Scale for Ammonia Refrigerating Plants, T. M. Gunn. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 211–214, 1 fig. Discusses performance and gives scale by which operating results may be compared with ideal ones for any pressure range.

ROLLING MILLS

Foreign Practice. Foreign Blooming Mill Practice, C. Kiesselbach. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 83–85, 7 figs. Series of production studies to determine proper number of passes; cooling due to roll contact rather than time intervals; power requirements at various reductions does not vary greatly. Translated from Stahl u. Eisen, Jan. 15, 1920.

STEAM ENGINES

Extraction-Type. Governing Devices of British Steam-Extraction Engines. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 173–174, 2 figs. Methods whereby satisfactory regulation is obtained on British engines.

STEAM GENERATORS

Electric. Laurentide Electric Steam Generators Largest Yet Installed, W. P. Muit. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 208–210, 4 figs. Two units, each consisting of three sections, connected on 6600-volt 3-phase circuit; each generator has normal capacity of 25,000 kw. and has absorbed 35,000 kw. and produced 50 tons of steam per hr.

STEAM POWER PLANTS

Compound-Engine. Plant of Brunswick-Balke-Collender Co., Muskegon, Michigan. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 200–205, 7 figs. Compound-engine non-condensing plant in which exhaust steam is used for process work, dry kilns and heating; water raised by air lift; special coal and ash handling.

STEAM TURBINES

Axial-Flow Ljungström. Axial-Flow Ljungström Turbine. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 229–230, 3 figs. Rotor is built up of a number of disks and annular rings; combined impulse-and-reaction-type unit forms part of 70-ton passenger locomotive that has seen regular service since March 1922; 1800 hp. developed at 9200 r.p.m. Translated from Zeit. des Vereines deutscher Ingenieure, Nov. 18, 1922.

Manufacture. Making Engineering Product on a Factory Basis, L. S. Love. Iron Age, vol. 111, no. 5, Feb. 1, 1923, pp. 333–336, 6 figs. Building turbines with consideration to variations of conditions of use by simplification and standardization.

STEEL

Fatigue Testing. Determination of the Fatigue-Resisting Capacity of Steel Under Alternating Stress, T. Robson. Engineering, vol. 115, no. 2977, Jan. 19, 1923, pp. 67–69, 4 figs. Describes arrangement adopted by Vincent Raven in testing department of North-Eastern Ry., machine used being Wohler cantilever type.

STEEL CASTINGS

Centrifugal Process. Special Products Made Centrifugally, George F. Tegan. Iron Age, vol. 111, no. 5, Feb. 1, 1923, pp. 337–338, 3 figs. Steel disk ingots for tires, wheels and other shapes produced by McConway process; billets and wire from such ingots.

Heat Treatment. Heat Treatment of Steel Castings, F. C. Langenberg. Iron Age, vol. 111, no. 6, Feb. 8, 1923, pp. 397–400, 2 figs. Methods of improving physical properties and bearing on specifications; effect on impact values of electric and open-hearth steel.

Heat Treatment of Steel Castings, H. C. Ihsen. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 95–99, 17 figs. Characteristics of steel castings in raw and thermally treated condition; consideration of correct treatment with relation to size and composition of casting.

STEEL MANUFACTURE

Calorific Value of Elements Used. Calorific Value of Steel-Making Elements, Henry D. Hibbard. Iron Age, vol. 111, nos. 2, 3 and 5, Jan. 11, 18 and Feb. 1, 1922, pp. 143–144, 211–213 and 347–349. Jan. 11: Chemistry of fusion or behavior and influence of each element on metallurgy of iron. Jan. 18: Role of silicon in bessemer and open-hearth furnace; proper use of aluminum; magnesium as deoxidizer. Feb. 1: Behavior of phosphorus, manganese chromium and other metals in steel processes; peculiarities of sulphur.

TERMINALS, LOCOMOTIVE

Design. An Innovation in Locomotive Terminal Design. Ry. Age, vol. 74, no. 4, Jan. 27, 1923, pp. 281–284, 3 figs. Rectangular or circular engine houses with inside cinder pits designed for promptly turning power. Designed by Nat. Boiler Washing Co., Chicago.

TERMINALS, RAILWAY

Chicago. Chicago Gets a New Passenger Terminal Plan. Ry. Age, vol. 74, no. 4, Jan. 27, 1923, pp. 263–267, 7 figs. Plans for new project by Chicago & West. Indiana, comprising study for new facilities on Dearborn Station site.